S9086–PF–STM–010/CH–408

FIRST REVISION

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 408
FIBER OPTIC CABLE TOPOLOGY
OPERATION, MAINTENANCE AND REPAIR

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FOREWORD

This Naval Ships Technical Manual describes operation and maintenance of Fiber Optic systems. It has been prepared for the training and use of both user and installation personnel. Information provided on operation, maintenance and installation is descriptive and procedural, and pertains to Fiber Optic systems aboard all U.S. Navy Ships.

This technical manual is divided into three sections with appendices covering different general areas of information.

Section 1	Introduction
Section 2	Fiber Optic Safety Procedures
Section 3	Shipboard Maintenance and Repair
Appendix A	Guide to Specifications and Standards
Appendix B	Design and Installation Considerations
Appendix C	Fiber Optic Repair Information Tables

Each section is divided into group paragraphs to enable users to focus attention on a specific topic in a general area. Tables and illustrations are arranged conveniently to aid in understanding text. Illustrations and tables are located as near as practicable to the point at which they are first referenced in the text.

Current and Planned Fiber Optic Training. Navy fiber optic training covers general theory, handling, safety and repair procedures. The current training philosophy includes a two-hour module for insertion into enlisted **A** Schools and officer indoctrination schools and a five-day stand-alone course for cable repair and connection. Courses are not rating specific. Operational training is not required because there is no planned maintenance for fiber optic cables and connectors.

Indoctrination Modules. Two-hour modules will be incorporated into existing **A** School curricula for some or all of the following source ratings: AE, AME, AT, AQ, AX, CE, CTM, DS, ET, EW, FC, FT, GM, GSE, IC, IM, MT, RM, ST, and TM. This module encompasses basic fiber optic principles, differences between fiber optic cable and copper wire, basic safety precautions, and special fiber optic cable handling procedures. The two-hour **A** School module may also be utilized for officer indoctrination training as appropriate at the Surface Warfare Officers School, Naval Submarine School, Officer Candidate School, Naval Aviation Candidate School, and other officer training activities.

Fiber Optic Cable Repair Course. All intermediate and organizational level repair skills are covered in a five-day course. This course provides an introduction to fiber optic technology and discusses the procedures for fault isolation, mechanical splicing, connections, spare cable or fiber selection, and repair testing. Hands-on splicing and connecting training is provided in laboratory sessions. Officers and enlisted personnel ranging from recent **A** School graduates to personnel with extensive sea experience are eligible for this course.

The Fiber Optic Cable Repair Course will initially be implemented at Fleet Training Center (FTC) Norfolk, and later at the Service School Command Annex San Diego, to provide easy access by fleet surface, submarine, and air personnel on each coast. It is estimated that four additional sites will be required to meet the total training requirement. Pearl Harbor, Memphis, Orlando, and New London are potential candidates for these additional training sites. Implementation of training locations will be phased with likely site initiation in FY94 (Norfolk), FY96 (San Diego), FY98, FY00, FY02, and FY04.

Construction Electrician Course. A five-day course which provides training in mechanical splicing, fusion splicing, and connection is in place at the Navy Construction Training Center, Gulfport. This course concentrates on shore-based applications.

Electronic Security Systems (ESS) Maintenance, Great Lakes. The ESS Maintenance **C** School includes one day of fiber optic theory and splicing/connecting techniques. Four days of system specific troubleshooting are also included. This system uses a go/no-go light signal rather than data carrying cables.

Data Systems Technicians (DS) A **School, Mare Island**. The DS **A** School six-hour module covers the same basic material as in the generic two-hour module with particular emphasis on computer repair.

Navy Electrical and Electronic Training Series (NEETS) Manual. The NEETS manual provides a general overview of fiber optic technology and is intended for self-instruction. The following sections are included: Background, Concepts, Design, Splices, Connectors, Couplers, Measurement Techniques, Optical Sources, Optical Detectors, Fiber Optic Sensors, Fiber Optic Systems, and Fiber Optic Installation and Repair.

Ships, training activities, supply points, depots, Naval Shipyards, and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA technical manuals shall be reported to the Commanding Officer, Naval Ship Weapon Systems Engineering Station (Code 5HOO, Port Hueneme, CA 93043–5007 on NAVSEA Technical Manual Deficiency/Evaluation Report, NAVSEA Form 9086/10. To facilitate such reporting, three copies of NAVSEA Form 9086/10 are included at the end of each bound part of each technical manual. All Feedback comments shall be thoroughly investigated and originators will be advised of action resulting therefrom. Extra copies of NAVSEA Form 9086/10 may be requisitioned from the Naval Publications and Forms Center (NPFC), Philadelphia, PA 19120–5009.

This technical manual is under the overall cognizance and maintenance responsibility of the Fiber Optics Program Office; Commander, Naval Sea Systems Command, Code 03K12, 2531 Jefferson Davis Hwy, Arlington, VA 22242–5160. Any questions concerning the manual’s applicability, content, distribution, or update should be directed to that office for resolution.

CHAPTER 408
FIBER OPTIC TOPOLOGY OPERATION, MAINTENANCE, AND REPAIR

SECTION 1.
INTRODUCTION

408–1.1 BACKGROUND

408–1.1.1 GENERAL. Fiber optic technology uses light to transmit data through micro-thin glass fibers. Typically, signals are converted from electrical to light signals, sent through an optical fiber and finally, converted back into the original electrical signals.

408–1.1.1.1 This manual focuses on fiber optic cable **topology**. That is, the fiber optic cable, connectors, interconnection (IC) boxes and switches between equipment (Figure 408–1–1). Fiber optic components and systems which are part of an equipment's internal components are not considered part of the fiber optic cable topology.

408–1.1.1.2 The demand for voice/data transmission is currently exceeding the capacity of metallic conductor systems within the Fleet. Fiber optics, on the other hand, provides not only a means of meeting required capacity, but offers significant advantages over copper wire. These include:

a. **Size and Weight**. Optical fiber cables are smaller and weigh less than copper cables.

b. **Cost**. The increased information carrying capacity (Bandwidth) enables one fiber optic cable to replace many conventional copper cables, reducing installation cost. In addition, with fiber optic cables there is no need for costly shielded or coax type cables. Electrical isolation of fiber also precludes ground loop problems eliminating the need for expensive grounding systems to prevent ground loop noise.

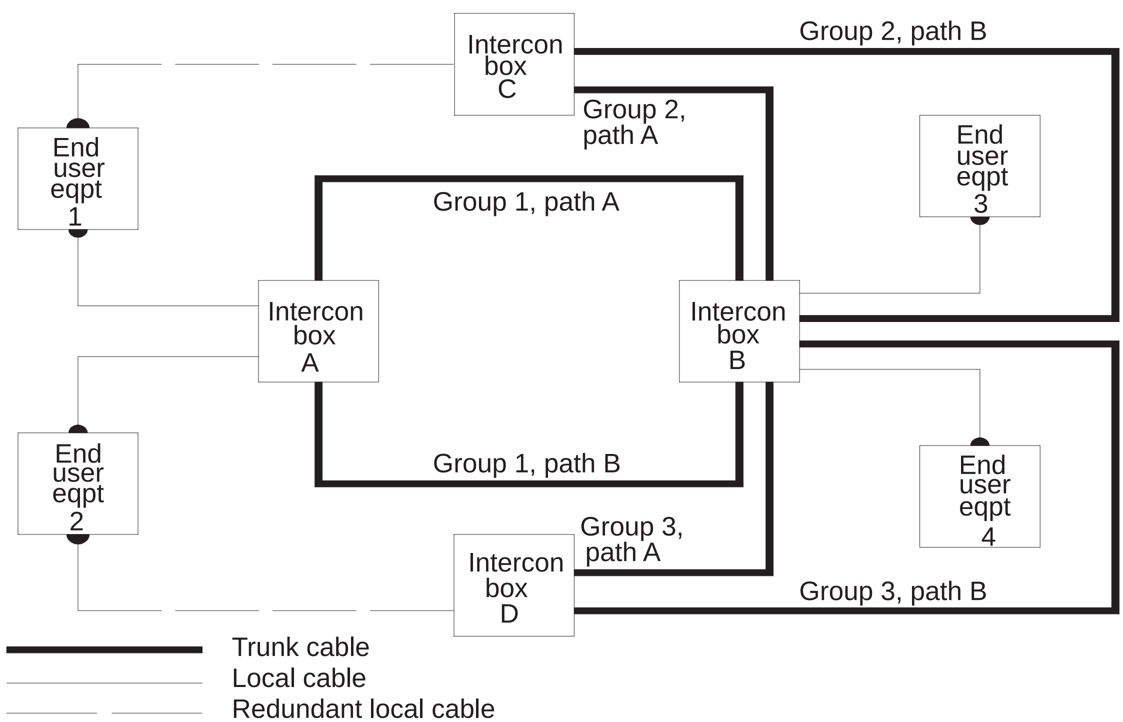

Figure 408–1–1. Fiber Optic Topology Functional Diagram

c. **Security**. It is difficult to tap a fiber optic cable without affecting the transmission enough to be detected. The lack of electromagnetic radiation precludes other methods of unwanted monitoring. Cross talk is reduced, as well.

d. **Isolation and Safety**. Since optical fibers carry no electricity, no grounding is required. There is also no possibility of shorts, sparking, or shock to personnel. Looking into the end of a transmitting optical fiber shall be avoided. Permanent damage or loss of vision can result from the transmitted wavelengths, most of which are invisible to the human eye.

e. **Increased Survivability**. Size and weight advantages permit greater redundancy and more alternate cable routes.

f. **Immunity**: to Electromagnetic Interference (EMI); Electromagnetic Pulse (EMP); and Radio Frequency Interference (RFI)

g. **Maintainability**. Fiber optic cables and connectors are not as subject to the degrading effects of moisture and corrosion as electrical components and therefore require less maintenance.

h. **System Growth**. Installation of fiber optic cables which allow different types of data transmittal provides for extensive system growth without additional cable installation.

i. **Better Performance**. Increased Bandwidth and data transmission accuracy improve the performance of certain systems and equipment, (Figure 408–1–2). Compared to other transmitting media, fiber permits simultaneous transmission of more diverse frequencies. This means that significantly more data can be sent/received through optical fiber than through copper wire. Additionally, attenuation versus modulation frequency is higher for metallic conductors. Thus, a single fiber can take the place of several copper conductors.

408–1.1.2 FIBER OPTIC CABLE TOPOLOGY (FOCT). The FOCT consists of trunk and local cables, splices, connectors, and fiber optic interconnection (IC) boxes. These local cable runs are generally short and are typically located outside the main cableways. Once inside the box, the local cable fibers are interconnected with

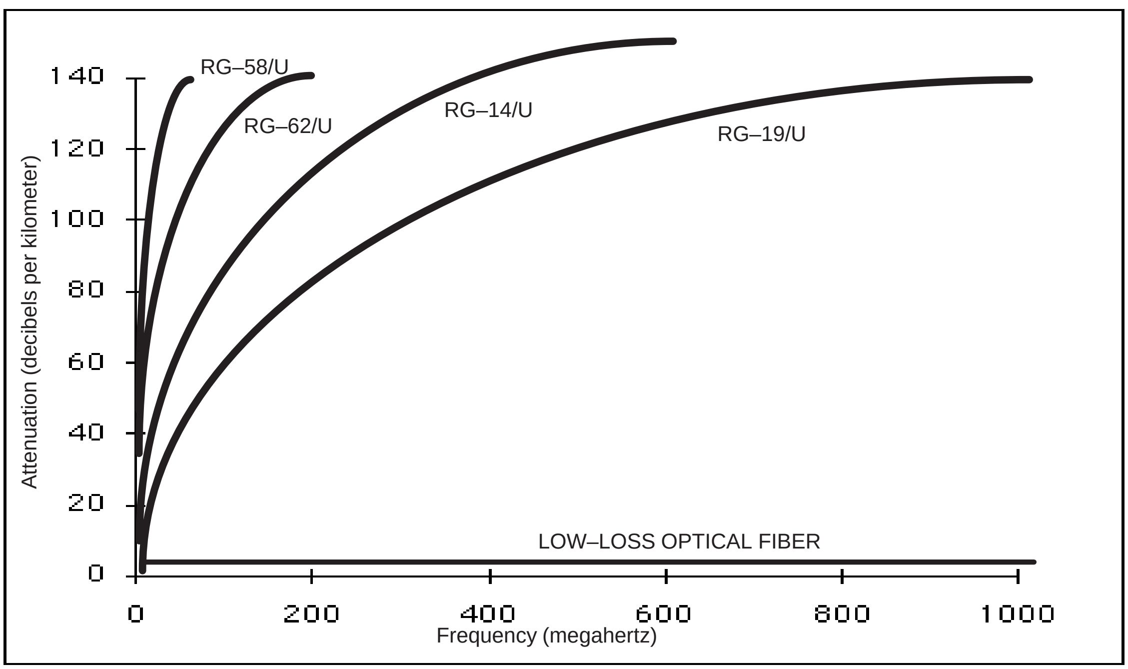

Figure 408–1–2. Best Bandwidth Capabilities of Transmitting Media

trunk cable fibers by splices or single termini connectors. Trunk cables provide the optical link between IC boxes. These cables are generally run in main cableways and typically have higher fiber counts than the local cables. The portion of the fiber optic topology consisting of trunk cables and IC boxes is referred to as the fiber optic cable plant (FOCP).

408–1.1.3 SERVICE AREAS. The configuration of the FOCP is dictated by the ship specification and the number, location, type and performance requirements of user systems. The optimum FOCP design is one that would allow the maximum number of user systems within a given area to share the same IC box and trunk cables. With this in mind, compartments containing fiber optic systems are grouped into zones referred to as service areas, and share common IC boxes.

408–1.1.4 TERMINATIONS. For termination of fibers, the two types of connectors (multiple and single terminus) and a single terminus mechanical splice have been approved for Navy use. Connectors are used in links that require periodic disconnections and reconnections. Multiple terminus connectors are used to connect the end user equipment to the FOCP and may be used without further protection from an enclosure. Single terminus connectors are used to connect individual fibers and must be protected in an IC box or equipment enclosure. Splices are more permanent and are used in links that do not require disconnection or require less link loss. The use of a splice is similar to that of the single terminus connector but the splice usually introduces a lower optical power loss, especially if actively tuned. Single terminus connectors are preferred because of their ruggedness and quick connect/disconnect time, unless otherwise specified in user system design documents.

408–1.1.5 GROWTH REQUIREMENTS. Fiber optic cable topology trunks generally have a minimum number of unallocated (growth) fibers. The unallocated fibers should be evenly distributed among all cables within the trunk group, which may have several paths. Local cables may include fibers designated for future growth but normally only if such a requirement is stipulated by the user system. In addition to growth fiber requirements, all IC boxes should contain additional termination points (either connector adaptor or splice tray positions) in excess of the number of termination points required to accommodate all trunk and local fibers entering the IC box during the initial installation.

408–1.2 TECHNICAL OVERVIEW

408–1.2.1 TYPES OF OPTICAL FIBER. An optical fiber, as used in the U.S. Navy, is a silica based fiber core and cladding with protective coating(s). Two types of optical fibers are utilized, multi-mode and single mode. Mode refers to a path light may follow in its movement through a fiber.

408–1.2.1.1 For Navy use, the basic physical difference between the two types is the optical fiber core size. The cladding, or outermost glass dimension, having a lower refractive index than the core, is constant at 125 micrometers for both fiber types. Core diameter of the single mode fiber is smaller (7 to 10 micrometers) than multi-mode (62.5 micrometers). In single mode, the fiber core is nearly the same width as the light’s wavelength, thus only a single pathway (mode) is available. Multi-mode optical fiber cores are wide enough to permit several light pathways.

408–1.2.1.2 Both single and multi-mode fibers are used and each has advantages and disadvantages versus the other. In general, light can be more easily introduced into, and connections made with multi-mode fibers. However, single mode fibers have lower attenuation and have a greater bandwidth capacity when used with a laser source. The 62.5/125 μm multimode fiber has been selected as the Navy standard multi-mode fiber because it offers the best mix of performance and human factors achievement.

408–1.2.1.3 An additional benefit of multi-mode fibers is that they allow the use of light-emitting diodes (LED) as transmitters. LEDs emit a relatively wide light beam which multi-mode fibers can accommodate. LEDs cost less, are more reliable, operate over a wider ambient temperature range, and last longer than the laser diodes necessary to transmit through single mode fibers. However, a narrower bandwidth must be tolerated when using LEDs.

CAUTION

LEDs used with optical fiber are much stronger than those used in wrist-watches and other numeric displays. See Section II for safety precautions.

408–1.2.1.4 Due to cost considerations associated with lasers, the Navy standard is to use multi-mode systems when possible. Therefore, unless stated otherwise, throughout the remainder of this text, **fiber** shall refer to 62.5/125 μm multi-mode fiber.

408–1.2.2 OPTICAL CABLE. MIL–C–85045 specifies the general requirements for Navy fiber optic cable. Although there are several cable designs, Navy research has shown that cable composed of Optical Fiber Cable Components (OFCC), (also called breakout cable), best meets Navy requirements. In OFCCs, the fiber's outermost glass layer, the cladding, is coated by a layer of plastic called the buffer (900 μm total diameter), surrounded with Kevlar for strength, and finished with a protective jacket (Figure 408–1–3).

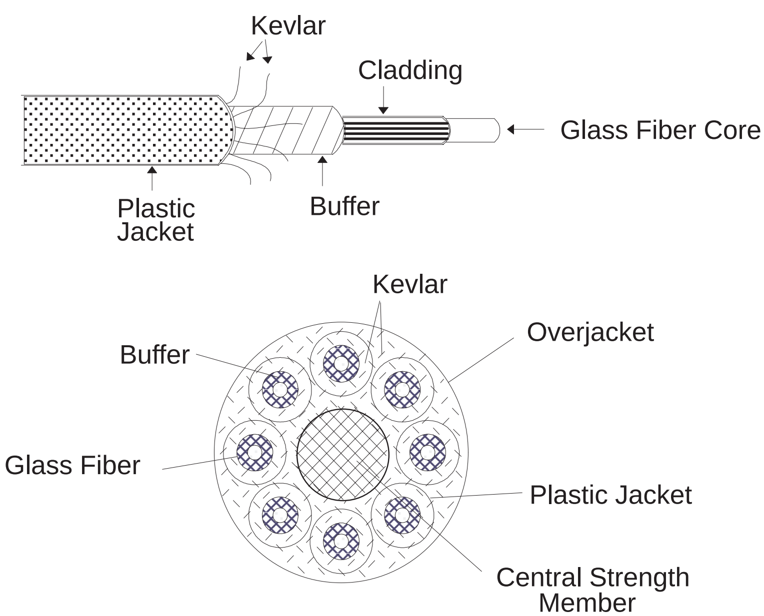

Figure 408–1–3. OFCC Cable

408–1.2.2.1 Glass fibers are stronger than copper of equal thickness. However, due to the small diameter of an optical fiber, the buffer is surrounded by Kevlar fibers to add strength. With a plastic cover over the Kevlar for protection against the environment, the entire OFCC measures about 2 mm in diameter.

408–1.2.2.2 There are five fiber optic cable sizes available. These are single, four, eight, twenty-four, and thirty-six fiber cables. These are sub-divided by characteristics such as type of jacketing or pressure performance.

408–1.2.3 HANDLING FIBER OPTIC CABLE. Installers and maintenance workers need to be aware of several constraints in handling fiber optic cables to avoid cable damage and loss of signal.

a. **Minimum Bend Diameter**. Fibers have a minimum bend diameter which is the smallest bend a cable can tolerate. If fibers are bent beyond that diameter, they may be permanently damaged, resulting in excessive signal loss. The minimum temporary (short term) bend diameter is normally 8 or more times the outside diameter of the cable. The minimum installed (long term) bend diameter is normally 16 or more times the outside diameter of the cable.

b. **Radial Compression**. Optical fiber does not withstand radial compression as well as copper because of microbends created in the fibers by the compression. These microbends result in increased signal loss. If cable clamps are used, do not compress the outer jacket of the cable when installing. Further, personnel performing maintenance or housekeeping duties near fiber cables must use special care to avoid striking the cable with tools or other objects which may cause deterioration or deform the integrity of the cable jacket.

c. **Moving and Relocating Cables**. Of particular concern is cable interference that occurs during ship modifications. A common practice is to disconnect and/or bend a copper cable out of the way when this occurs; this should be done only with extreme caution when dealing with a fiber cable. The special precautions discussed above must be observed when moving a fiber optic cable.

d. **Pulling Cables**. Care shall be given when pulling optic cables through fittings and grommets to avoid kinking or exceeding the cable's pull strength. Also, avoid snagging or tearing the cable jacket when pulling around sharp edges in cableways.

e. **Radiation**. A final constraint is that optical fiber may become opaque over time when exposed to radiation bombardment. Therefore, fiber optic cable shall not be run in radioactive areas.

408–1.3 CONNECTORS AND SPLICES

408–1.3.1 GENERAL. Use of Navy qualified or approved connectors and splices ensures reliable interfaces with low signal loss. Considerations involve accurate cleaving and polishing of individual fiber ends to ensure proper optical and mechanical joining. While there will always be some losses over a fiber interface, appropriate preparation and use of recommended mechanical connections keep these within Navy tolerances. Detailed descriptions of fiber optic and related components can be found in specifications listed Table 408–1–1.

408–1.3.2 HANDLING. For the following reasons, connectors and splices should not be unmated unless it is absolutely necessary:

408–1.3.2.1 The introduction of dust and dirt between the optical fibers could disrupt system operation. Furthermore, exposed fiber ends are highly subject to scratches which may increase signal loss.

408–1.3.2.2 When using multi-terminus, or locking style single terminus connectors, under or over torque of screw-on coupling mechanisms may damage the connector or impair system performance.

Table 408–1–1. FIBER OPTIC CABLE TOPOLOGY MILITARY SPECIFICATION

Fiber Optic Components	Military Specification
Fiber	MIL-F-49291
Cable	MIL-C-85045
Transmitter	MIL-T-24791/1
Receiver	MIL–R–24792/2
Connector	MIL-C-28876, MIL-C-83522
Splice	MIL-S-24623
Interconnection box	MIL-I-24728
Switch	MIL-S-24725

408–1.3.2.3 Although rotary mechanical splices are reusable, repeatedly opening and closing the devices should be avoided. Scratches in the fiber or misalignment of the splice may result from repeated use.

408–1.3.3 ROTARY SPLICE. The splice approved for U.S. Navy use is the rotary mechanical splice (Figure 408–1–4). With this device, the two fiber ends are placed in a pair of matched glass ferrules. The ferrule and the fiber ends are highly polished for butt splicing. A drop of index matching material (a liquid or gel used to minimize losses by filling minute air gaps to reduce signal losses) may be placed between the ends of the ferrule

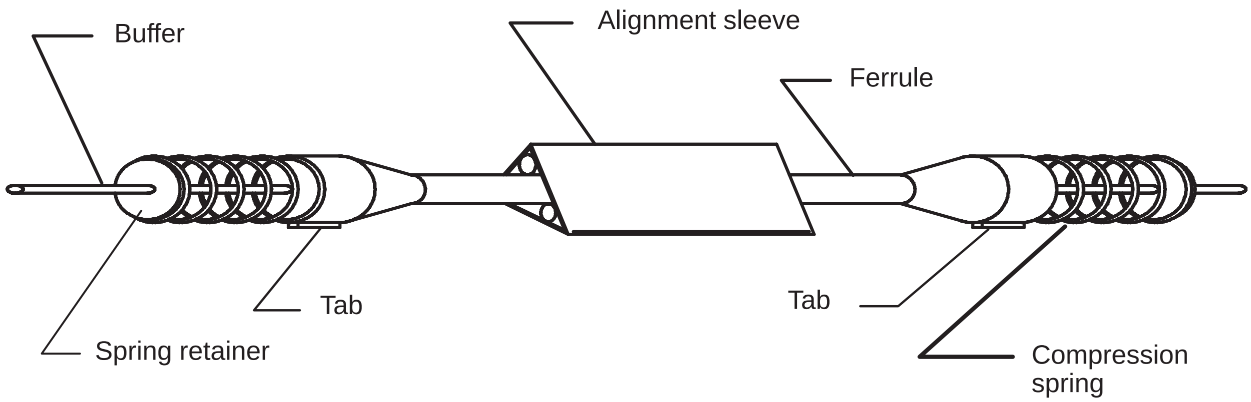

Figure 408–1–4. Rotary Mechanical Splice

assemblies held together by an alignment sleeve. With this design, splice losses do not vary significantly with changes in temperature or other environmental/mechanical conditions.

408–1.3.4 SINGLE TERMINUS CONNECTOR. Single Terminus (ST type) connectors (MIL–C–83522/16) are the approved connectors for Navy use. They can be used on single fiber cable (OFCC's) within interconnection boxes or in locations protected from the environment. The ST connector is a ferrule tipped plug that employs a twist–lock latch (Figure 408–1–5). This design ensures proper fiber alignment, acceptable signal loss, and minimal connect/disconnect times.

408–1.3.5 HEAVY DUTY MULTI-TERMINUS CONNECTOR. Heavy duty multi-terminus connectors (MIL–C–28876) are approved for shipboard use with multi-fiber cables. The standard Navy multi-terminus connector is a circular plug and receptacle style connector. They can have straight or angled backshells, can have various mountings, can provide different degrees of environmental protection and are used to connect local fiber cables to equipment. Multiple terminus connectors are used to couple fiber optic cables containing more than one OFCC using multiple termini within a single connector housing.

408–1.4 OTHER FOT COMPONENTS

408–1.4.1 Switches (MIL–S–24725) are used to change optical signals from one fiber path to another. Switches are most commonly connected by mechanical splices or connectors, either to other switches, repeaters, network equipment, or to local or trunk cables.

408–1.4.2 Interconnection boxes (MIL–I–24728) may protect splices, connectors, couplers and switches from environmental conditions and mechanical stress. Figure 408–1–6 depicts a typical internal IC box configuration.

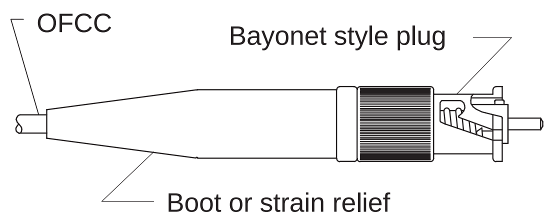

Figure 408–1–5. ST Connector

408–1.4.3 Normal electrical equipment handling precautions should be observed for fiber optic modems, repeaters, and equipment racks as these are electrical components.

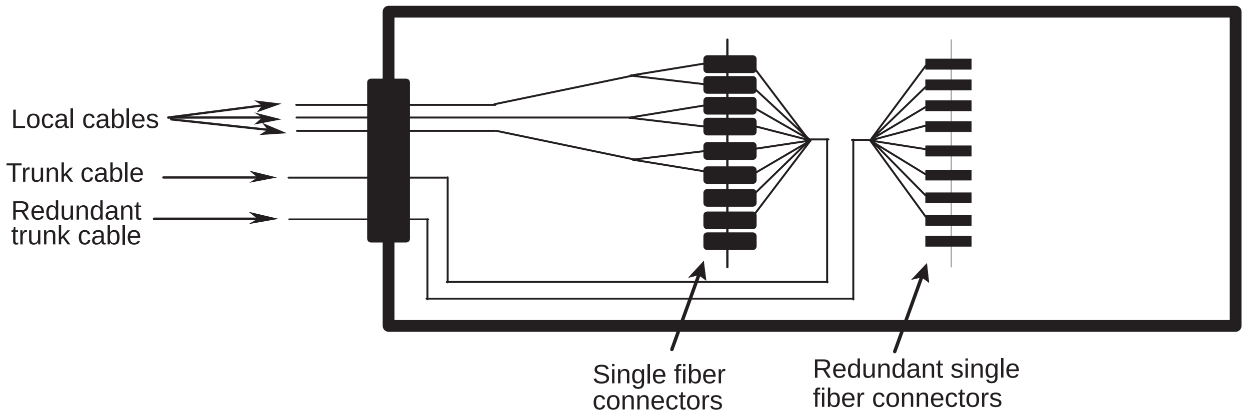

Figure 408–1–6. Typical Fiber Optic Interconnection Box Configuration

SECTION 2.
SAFETY PRECAUTIONS

408–2.1 GENERAL

408–2.1.1 Fiber optic systems can occasionally be hazardous. Potential hazards include injury from the fiber or chemicals and solvents used during repair procedures. Optical power is also a potential hazard. There are some basic precautions which should be observed to preclude any danger.

408–2.2 FIBER HAZARDS

408–2.2.1 The fiber core and cladding are made of glass and can shatter when they are broken or cut. This can produce tiny shards of glass which can easily embed in the skin or eyes. Fibers are particularly worrisome because they are so small that they are very difficult to see and remove. Safety glasses or safety goggles shall be worn at all times when handling optical fiber. Do not touch fiber ends as they will easily puncture the skin. After handling bare fiber, wash hands thoroughly to avoid puncture from any clinging pieces of optical fiber.

408–2.3 CHEMICALS AND SOLVENTS

408–2.3.1 Various chemicals and solvents are used during splicing and connection procedures. They may present flammable hazards and should be used in areas with good ventilation if possible. Adhesives used in the termination process are sensitizers. Prolonged skin contact with these materials will cause irritation and should be avoided.

408–2.4 NOXIOUS OR TOXIC VAPORS

408–2.4.1 Cable jacket and strength members are composed of non-toxic, low smoke materials. Most cable materials will only present hazards under extreme conditions where these materials are subject to a fire. The basic precautions of avoiding smoke filled areas without breathing apparatus should be observed. Also, adhesives used in the termination process emit vapors which can be irritating if used in unventilated areas for extended periods. If possible, adhesives should be used in ventilated areas.

408–2.5 OPTICAL POWER HAZARDS

408–2.5.1 Planned military applications are limited to Class 1, 2 and 3 optical sources. Class 3 lasers, are currently used for Optical Time Domain Reflectometry (OTDR). These classes are defined as follows:

a. **Class 1**: Incapable of producing potentially hazardous optical radiation levels during normal operation and maintenance. Class 1 systems are safe for unaided viewing; i.e., without the use of a microscope or eye loupe (magnifying glass). Most military systems use Class 1 sources.

b. **Class 2 Systems, Low Power**: Designation applied to some light emitting diodes (LED). A Class 2 system is required to have cautionary labels affixed to the external surfaces of the light source.

c. **Class 3**: Lasers for OTDR use. Also, they are anticipated to be used for other purposes, such as communication lasers in high speed single mode applications.

408–2.5.2 Light exiting from a fiber is highly divergent. Accordingly, at distances greater than 10 inches, the power density (or optical power per radiant area) from any Class 1 or Class 2 system has dissipated to levels which allow safe unaided viewing. However the basic rule is: do not stare into any fiber unless you know there is no light being emitted from the fiber. If the fiber end must be viewed, hold it a minimum of 10 inches from your eye and limit viewing exposure to less than 5 seconds.

408–2.5.3 Ideally, an Optical Loss Test Set (OLTS) is the instrument that should be used to measure the optical power coming from the fiber.

408–2.5.4 As operational light wavelengths are not visible, light energy may still be emanating from a fiber (invisible infrared (IR)). Eye damage could occur without awareness by staring into the end of such a fiber. The use of a microscope or eye loupe greatly increases the potential for eye damage.

408–2.5.5 If connectors or splices must be disconnected, plastic end caps should be placed over the ends to block any hazardous light emissions. End caps will also protect the fiber ends from abrasion and dirt.

408–2.6 ULTRAVIOLET LIGHT HAZARDS

408–2.6.1 UV light is used during splicing procedures to cure the adhesive used to attach the fiber within the splice. Most UV light sources are well shielded. UV protection should be worn at all times while operating UV lights to avoid eye damage. No attempt should be made to use the UV source if the shield is missing or damaged.

408–2.7 ELECTRIC TEST EQUIPMENT PRECAUTIONS

408–2.7.1 Verify that all electrical safety checks have been performed on electric test equipment prior to use.

SECTION 3.
SHIPBOARD MAINTENANCE AND REPAIR

408–3.1 GENERAL

408–3.1.1 This section provides an overview of organizational level maintenance capabilities. For specifics of how to perform the various maintenance functions, see the sections on Maintenance Procedures, Repair Procedures, and Description and Use of Test Equipment.

408–3.1.2 Due to the nature of fiber optic cable, only corrective maintenance is performed. Preventive maintenance is not recommended for fiber optic systems; damage may occur. For example, unneeded demating/mating of connection hardware or flexing of the fibers subsequent to installation could degrade transmission performance.

408–3.2 SHIPBOARD CAPABILITIES

408–3.2.1 FAULT ISOLATION. The first step of corrective maintenance is to determine the location at which a fault has occurred. This process requires the use of one or more types of test equipment and is discussed in the Fault Isolation Procedure section.

408–3.2.2 MAINTENANCE AND REPAIR. Organizational level maintenance and repair is divided into two categories – permanent and temporary.

408–3.2.2.1 Permanent maintenance refers to replacement of fiber optic cable, connectors, connector termini, splices, switches, or interconnection boxes. Permanent maintenance of connectors, connector termini, switches and splices is normally performed at the organizational (local command or shipboard) level. Permanent maintenance of cable or interconnection boxes is normally performed at the intermediate (SIMA, tender, etc) level.

408–3.2.2.2 Temporary cable maintenance refers to the transfer of affected signals to a redundant path. This is accomplished by switching connections to redundant or spare fibers or cables. This may be accomplished at the equipment connector (for equipments with completely redundant hookups) or in the interconnection box (when only redundant or spare trunk fibers have been installed). In the case of cableway damage, single terminus connectors installed in temporary interconnection boxes can be used for temporary cable repairs when redundant or spare fibers or cables are not available.

408–3.3 TEST EQUIPMENT

408–3.3.1 DESCRIPTION AND USE OF TEST EQUIPMENT. Repair of fiber optic systems requires knowledge of the use of fiber optic test equipment. The test equipment used to repair fiber optic systems includes:

a. Optical Time Domain Reflectometer (OTDR)

b. Mini–OTDR

c. Optical Loss Test Set (OLTS)

d. Optical Leak Detector (OLD)

WARNING

Verify that all electrical safety checks have been performed on electric test equipment prior to use.

408–3.3.2 OPTICAL LOSS TEST SET (OLTS). The OLTS is used to measure the total signal loss of an optical link. It is also used to measure the optical power output of an optical transmitter or an optical fiber in a cable assembly. An OLTS consists of an optical source and an optical detector, in a single unit. The optical source is used to launch optical power into an optical link. The optical detector is used to measure the amount of optical power coupled out of the optical link.

408–3.3.2.1 When the loss of signal in an optical link is being measured, two calibrated OLTS and multiple OLTS test jumper cables (NAVSEA DWG 6877804) having high quality connectors or splices are used (Figure 408–3–1). The jumper cables are supplied separately from the test equipment as a jumper set. There is a different jumper set for each type of connector or splice available. The “launch” OLTS launches optical power into the optical link through the “launch” test jumper. The “detect” OLTS measures the output optical power of the optical link through the “detect” test jumper. The reference test jumper cable calibrates or zeros the power level coupled from the optical source into a test jumper cable.

408–3.3.2.2 Table 408–3–1 describes which jumper cable connectors to use with which optical link splices/connectors.

408–3.3.2.3 The procedure used in operating the OLTS to measure the power loss in an optical link terminated with MIL–C–83522/16 connectors is shown in Figure 408–3–1:

Table 408–3–1. TEST CABLE/OPTICAL LINK MATCHES

Optical link connector/splice	Test cable connection at OLTS	Test cable connection at optical link	Test cable type
MIL-C-83522/16	MIL-C-83522/16	MIL-C-83522/16	Single fiber
MIL-S-24623/4	MIL-C-83522/16	MIL-S-24623/4	Single fiber
MIL-C-28876 plug	MIL-C-83522/16	MIL-C-28876 receptacle	Multi-fiber

NOTE

Refer to manufacturer’s technical manual for specific user test equipment.

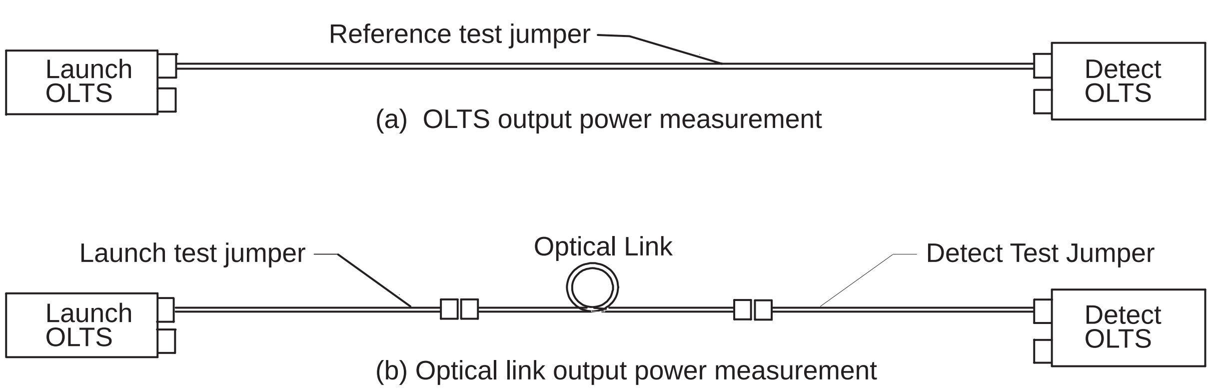

Figure 408–3–1. Optical Link Loss Measurement

Step a – Turn on both OLTS and verify that:

1. Low battery indicators are not on.

2. OLTS are in measure mode (not calibration mode).

3. Optical power displays are in dBm.

4. Optical source of the **launch** OLTS is turned on.

5. Optical wavelength settings of both the OLTS are at 1300 nm.

Step b – Zero the display of the **detect** OLTS (Figure 408–3–1 (a)).

1. Connect the input connector of the reference jumper cable to the optical source of the **launch** OLTS. If the input connector is not designated, choose one.

2. Connect the output connector of the reference jumper cable to the optical detector of the **detect** OLTS.

3. Zero the **detect** OLTS by pressing the **Reference** or **Db** button (the OLTS display should go to zero).

Step c – Measure the power loss of the optical link (see Figure 408–3–1 (b)).

1. Disconnect the output connector of the reference jumper cable from the **detect** OLTS and connect it to the optical link (this jumper cable now becomes the **launch** test jumper).

2. Connect the output end of the optical link to the **detect** test jumper.

3. Connect the output end of the **detect** test jumper to the **detect** OLTS detector.

4. Loss of the optical link (in dB), including end connectors, is the value displayed on the **detect** OLTS.

408–3.3.2.4 The procedure used in operating an OLTS to measure the loss of an optical link terminated with MIL–S–24623/4 splices or MIL–C–28876 connectors is illustrated in Figure 408–3–1 and described below.

Step a – Turn on both OLTS and verify that:

1. Low battery indicators are not on.

2. OLTS are in measure mode (not calibration mode).

3. Optical power displays are in dBm.

4. Optical source of the **launch** OLTS is turned on.

5. Optical wavelength settings of both OLTS are at 1300 nm.

Step b – Zero the display of the **detect** OLTS.

1. Connect the input connector of the reference jumper cable to the optical source of the **launch** OLTS. If the input connector is not marked, choose one.

2. Connect the output connector of the reference jumper cable to the optical detector of the **detect** OLTS.

3. Zero the **detect** OLTS by pressing the **Reference** or **dB** button (the OLTS display should go to zero).

Step c – Measure the output optical power of the optical link.

1. Disconnect the reference jumper from both the **launch** OLTS and the **detect** OLTS.

2. Connect the input end of the **launch** test jumper to the source of the **launch** OLTS.

3. Connect the output end of the **launch** test jumper to the input end of the optical link.

4. Connect the output end of the optical link to the input end of the **detect** test jumper.

5. Connect the output end of the **detect** test jumper to the **detect** OLTS detector.

6. Loss of the optical link (in dB) including end connectors is the value displayed on the **detect** OLTS.

408–3.3.2.5 To measure the optical power output of an active optical fiber in a cable assembly, refer to Figure 408–3–2:

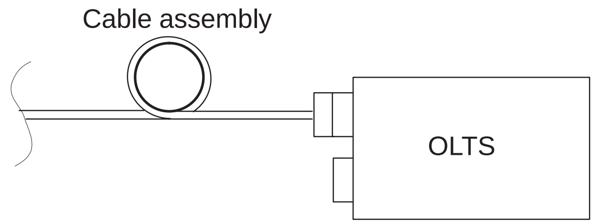

Figure 408–3–2. Optical Fiber Output Power Measurement

Step a – Turn the OLTS on and verify that:

1. Low battery indicator is not on.

2. OLTS is in measure mode (not calibration mode).

3. Optical power display is in dBm.

4. Optical source of the OLTS is turned off.

5. Optical wavelength setting of the OLTS is the same as the system wavelength.

Step b – Measure the optical power output of the optical fiber in the cable assembly.

1. Connect output connector of the optical fiber in the cable assembly to the OLTS detector.

2. Value displayed on the OLTS is the power output of the optical fiber in dBm.

408–3.3.2.6 To measure the optical power output of an optical transmitter with a fiber or cable pigtail refer to Figure 408–3–3:

Step a – Turn the OLTS on and verify that:

1. Low battery indicator is not on.

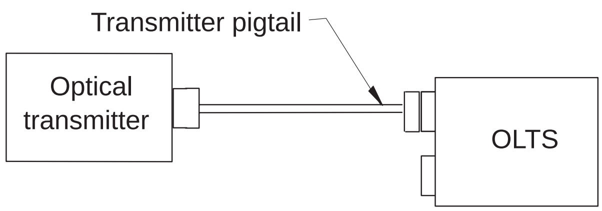

Figure 408–3–3. Optical Transmitter Output Power Measurement

2. OLTS is in measure mode (not calibration mode).

3. Optical power display is in dBm.

4. Optical source of the OLTS is turned off.

5. Optical wavelength setting of the OLTS is the same as the transmitter wavelength.

Step b – Measure the power output of the optical transmitter pigtail.

1. Connect output connector of the optical transmitter output pigtail to the OLTS detector.

2. Value displayed on the OLTS is the optical power output of the optical transmitter in dBm.

408–3.3.2.7 Measuring the optical power output of an optical transmitter configured with a connector adapter requires one test jumper cable. The procedure used in operating an OLTS to measure the optical power output of an optical transmitter configured with a connector adapter is shown in Figure 408–3–4:

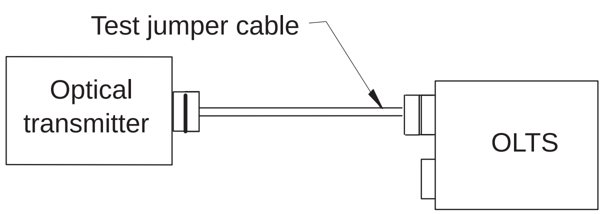

Figure 408–3–4. Optical Transmitter Output Power Measurement

Step a – Turn the OLTS on and verify that.

1. Low battery indicator is not on.

2. OLTS is in measure mode (not calibration mode).

3. Optical power display is in dBm.

4. Optical source of the OLTS is turned off.

5. Optical wavelength setting of the OLTS is the same as the transmitter wavelength.

Step b – Measure the power output of the test jumper cable assembly.

1. Connect the input end of the test jumper cable to the optical transmitter connector adapter.

2. Connect the output connector of the test jumper cable to the OLTS detector.

3. The value displayed on the OLTS is the optical power output of the optical transmitter in dBm.

408–3.3.3 MINI-OTDR. The Mini-OTDR is used to locate fiber breaks in installed optical fibers. The Mini-OTDR is also used to locate connectors or splices that have unusually high losses. The Mini-OTDR requires access to only one end of an optical link in order to make a measurement. Its primary difference from an OTDR is that the Mini-OTDR is smaller and simpler with more limited capabilities.

408–3.3.3.1 When evaluating optical fibers, connectors or splices in an optical link, a long (>50m) test jumper cable is used between the Mini-OTDR and the cable assembly under test. The long jumper cable is used so that the dead zone at the Mini-OTDR interface does not affect Table 408–3–2 describes which jumper cable connectors to use with which optical link splices/connectors.

Table 408–3–2. TEST CABLE/OPTICAL LINK MATCHES

Optical link connector/splice	Test cable connection at Mini-OTDR	Test cable connection at optical link	Test cable type
MIL-C-83522/16	MIL-C-83522/16	MIL-C-83522/16	Single fiber
MIL-S-24623/4	MIL-C-83522/16	MIL-S-24623/4	Single fiber
MIL-C-28876 plug	MIL-C-83522/16	MIL-T-29504/15	Single fiber
MIL-C-28876 receptacle	MIL-C-83522/16	MIL-T-29504/14	Single fiber

408–3.3.3.2 See the Mini-OTDR manufacturer's manual for detailed operating procedures. **The following is provided only as an illustrative example.**

NOTE

Refer to manufacturer technical manual for specific user test equipment.

408–3.3.3.3 The procedure used in operating an Mini-OTDR to detect and locate connectors or splices with high losses or broken optical fibers is shown in Figure 408–3–5 and described below:

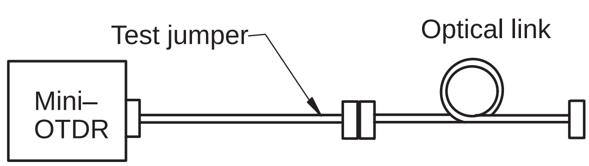

Figure 408–3–5. Mini-OTDR Cable Assembly Measurement

Step a – Plug the Mini-OTDR into an electrical outlet. In cases where no electrical outlets are nearby, operate the Mini-OTDR using its internal battery.

Step b – Turn the Mini-OTDR on and set (using the setup menu):

1. Measurement mode to **Auto**.

2. Distance range to **Auto**.

3. Pulse width to the smallest setting available.

4. Index of refraction to the value used during installation testing (**1.490** may be used if the value used for the installation testing is not known).

5. Splice loss threshold to **0.2 dB**.

6. Reflectance threshold to **20 dB**.

7. Fiber end threshold to **5 dB**.

8. Event order to **distance**.

Step c – Connect the input end of the test jumper cable to the Mini-OTDR.

Step d – Connect the output end of the test jumper cable to the optical link.

Step e – Analyze the optical link.

1. Press **Start** and scan the test jumper cable and the optical link.

Step f – Verify the data shown in the event table.

1. Expand the horizontal scale using the **<** button so that the trace fills the display.

2. Verify that each link connector and splice shown on the trace has a corresponding entry included in the event table.

3. Verify that each entry in the event table has a corresponding connector or splice shown on the trace.

Step g – Compare the list of connector and splice positions and losses in the event table to the link installation data. If the installation data is not available compare the measured component losses to the component loss value limits shown Table 408–3–3.

NOTE

The optical loss values of connectors and splices measured with the Mini-OTDR may not be accurate and should only be used to highlight unusual and possibly defective parts.

Table 408–3–3. COMPONENT LOSS VALUE LIMITS

Component	Loss Limit
Connector	1.0 dB
Splice	0.6 dB
Fiber	4.5 dB/km

408–3.3.4 OPTICAL LEAK DETECTOR (OLD). The OLD is used to physically locate optical fiber breaks or regions of high loss in an optical fiber or an OFCC of a multi-fiber cable. These breaks or regions of high loss are frequently at the back of optical connectors or splices. The OLD can only be used with buffered fibers or the OFCC. The OLD will not detect fiber breaks inside of a multifiber cable unless the outer jacket is removed and the OFCCs are exposed.

408–3.3.4.1 When evaluating optical fibers, connectors, or splices in an optical link, a test jumper cable is connected between the OLD and the cable assembly under Table 408–3–4 describes which jumper cables to use with which optical link splices/connectors.

NOTE

Refer to manufacturer's technical manual for specific user test equipment

Table 408–3–4. TEST CABLE/OPTICAL LINK MATCHES

Optical link connector/splice	Test cable connection at Mini-OTDR	Test cable connection at optical link	Test cable type
MIL-C-83522/16	MIL-C-83522/16	MIL-C-83522/16	Single fiber
MIL-S-24623/4	MIL-C-83522/16	MIL-S-24623/4	Single fiber
MIL-C-28876 plug	MIL-C-83522/16	MIL-C-28876 receptacle	Multi-fiber

408–3.3.4.2 The procedure used in operating an OLD to detect and locate regions of high loss or breaks in installed optical fibers or single fiber cables is as described below.

Step a – Plug the OLD into an electrical outlet (in cases where no electrical outlets are nearby, the OLD may be operated using the internal battery).

Step b – Connect the input connector of the test jumper cable to the OLD. If the input connector is not designated, choose one.

Step c – Connect the output connector of the test jumper cable to the optical cable assembly under test.

Step d – Turn the OLD transmitter on and set the output power to maximum.

Step e – Turn the OLD detector on (the LED indicator will slowly flash indicating that the OLD detector is energized).

Step f – Move the OLD detector along the outside of the fiber or single fiber cable. The OLD detector will emit a high pitched tone and the LED indicator will remain on if light is detected. Any light detected anywhere other than at the fiber end is an indication of either an optical fiber break or severe bending of the optical fiber.

408–3.3.5 OPTICAL TIME DOMAIN REFLECTOMETER (OTDR). The OTDR is used to locate fiber breaks or faults and to measure the attenuation of installed optical fibers. It also identifies and evaluates optical connection losses. **An OTDR should not be used to measure the attenuation of installed optical fibers which are less than 50 meters in length**. An OTDR requires access to only one end of the optical link in order to make a measurement. However, OTDR measurements are always made from each end of the optical link as the result may not be the same in both directions. This is because an OTDR only measures reflected light, not actual loss, and the reflected light is affected by more than component losses. If measurements from each end of an optical link do not match, use an average of the two values.

NOTE

The OTDR and the Mini-OTDR are both optical time domain reflectometers. The OTDR has greater capability than the Mini-OTDR.

408–3.3.5.1 When an OTDR is used to evaluate an optical link, a long (>50m) test jumper cable is used between the OTDR and the optical link under test. The long jumper cable is used so that the dead zone at the OTDR interface does not affect the measurements. A second test jumper is connected at the end of the optical link if the total optical link loss is to be measured.

408–3.3.5.2 The following is provided only for illustrative purposes. See the OTDR manual for detailed operating procedures.

NOTE

Refer to manufacturer's technical manual for specific user test equipment.

408–3.3.5.3 The procedure used in operating an OTDR to measure the loss of an installed optical fiber (not including connector losses) is shown in Figure 408–3–6 and described below:

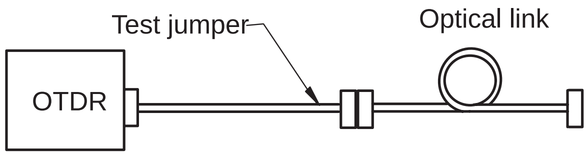

Figure 408–3–6. OTDR Fiber Loss Measurement

Step a – Plug the OTDR into an electrical outlet.

Step b – Turn the OTDR on and set.

1. Pulse width to the smallest setting available.

2. Distance display to the **origin** (the beginning of the test jumper cable).

3. Loss mode to **dB** (2 point loss mode).

4. Index of refraction to the value used during the installation testing (**1.490** may be used if the value used for the installation testing is not known).

Step c – Connect the input end of the test jumper cable to the OTDR.

Step d – Connect the output end of the test jumper cable to the optical link containing the optical fiber to be tested.

Step e – Scan the optical link to set up the screen display.

1. Scan the test jumper cable and the optical link using the fastest scan available.

2. Move the cursors to 0.

3. Expand the horizontal and vertical scales so that the trace fills the display, but is completely contained in the display.

Step f – Measure the loss of the optical fiber.

1. Scan the test jumper and the optical link using a slow scan.

2. Move the first cursor to the beginning of the straight portion of the trace after the input connector of the fiber (point z_1, Figure 408–3–7).

3. Move the second cursor to the end of the trace immediately before the output connector of the fiber (point z_2, Figure 408–3–7).

4. Observe the OTDR display and record loss ($L_1 = P_2 – P_1$) and distance ($D_1 = z_2 - z_1$) of the fiber between the cursors.

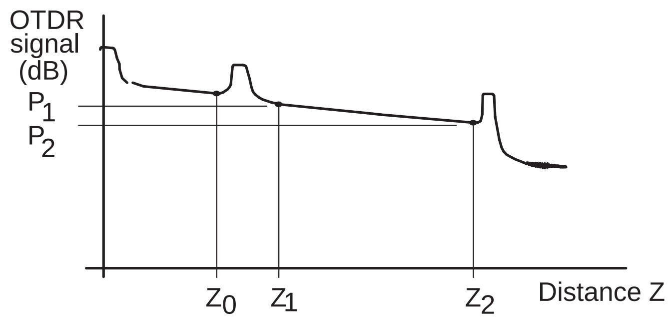

Figure 408−3−7. OTDR Measurement of Optical Fiber Loss

5. Move the first cursor immediately before the input connector of the fiber (point z_0, Figure 408–3–7).

6. Observe the OTDR display and record the length ($D_2 = z_2 - z_0$) of the fiber.

7. Calculate the loss of the fiber using

$L_f = L_1 \times D_2/D_1$.

408–3.3.5.4 To measure the loss with an OTDR of an optical link in an installed cable assembly (including the optical loss of end connectors in the optical link) refer to Figure 408–3–8:

Step a – Plug the OTDR into an electrical outlet.

Step b – Turn the OTDR on and set:

1. Pulse width to the shortest setting available.

2. Distance display to display from the **origin** (the beginning of the test jumper cable).

3. Loss mode to **dB** (2 point loss mode).

Index of refraction to the value used during installation testing (**1.490** may be used if the value used for installation testing is not known).

Step c – Connect the input end of the first test jumper cable to the OTDR.

Step d – Connect the output end of the test jumper cable to the optical link.

Step e – Connect the output end of the optical link to the input end of the second test jumper cable.

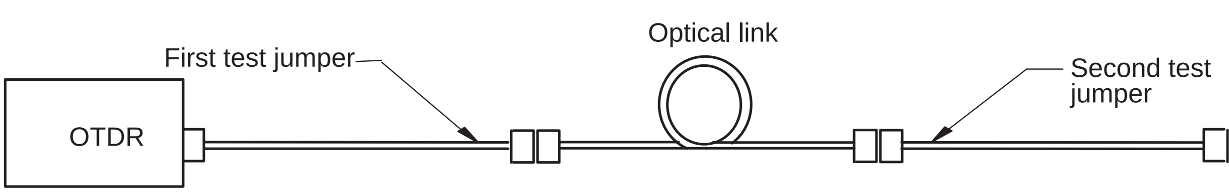

Figure 408−3−8. OTDR Optical Link Loss Measurement

Step f – Scan the optical link to set up the screen display.

1. Scan the test jumper cables and the optical link using the fastest scan available.

2. Move the cursors to 0.

3. Expand the horizontal and vertical scales so that the trace fills the display, but is completely contained in the display.

Step g – Measure the loss of the optical link.

1. Scan the test jumper cables and the optical link using a slow scan.

2. Move the first cursor immediately before the first connector of the optical link (point z_0 of Figure 408–3–9).

3. Move the second cursor to the beginning of the linear portion of the trace after the last connector of the optical link (point z_1 of Figure 408–3–9).

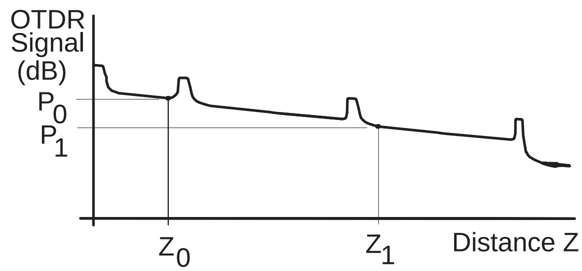

Figure 408–3–9. OTDR Measurement of Optical Link Loss

4. Observe the OTDR display and record loss ($L_1 = P_1 - P_0$) and distance ($D_1 = z_1 - z_0$) of the segment between the cursors.

408–3.3.5.5 To measure the loss with an OTDR of an optical connector in an installed cable assembly see Figure 408–3–10:

Step a – Perform steps a through f of paragraph 408–3.3.5.4, above.

Step b – Measure the loss of the optical connector.

1. Scan the test jumper cables and the optical link using a slow scan.

2. Move the first cursor immediately before the connector to be tested (point z_0 of Figure 408–3–10).

3. Move the second cursor to the beginning of the linear portion of the trace after the connector to be tested (point z_1 of Figure 408–3–10).

4. Observe the OTDR display and record the loss ($L_1 = P_1 - P_0$) and the distance ($D_1 = z_1 - z_0$) of the segment between the cursors.

408–3.4 TAGGING AND IDENTIFICATION

408–3.4.1 GENERAL. All cables shall be marked in accordance with the ship specification and system drawings and as specified below.

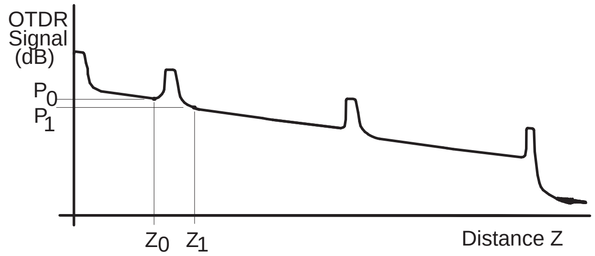

Figure 408–3–10. OTDR Measurement of Optical Connector Loss

408–3.4.2 CABLE TAGS. Cable identification tags external to the equipment shall be in accordance with MIL–STD–2189/305. Cable tags shall be of a size suitable to accommodate the required marking but shall have a minimum width of 0.5 inch (13mm). Tags and strips for marking cables shall be of soft aluminum tape having a natural finish. Capital letters shall be used on cable tags; height of all letters shall be not less than 3/16 inch (5mm), and letters and numbers shall be embossed to at least 1/64 inch (1mm) above the surface.

1. Within interconnection boxes, all permanently installed optical fibers are tagged in a manner similar to electric wires. Heat shrink tubing is used to identify fibers at their termination point within an IC box. The tubing shall be white.

2. All permanently installed cables shall be tagged to each point of connection, and on both sides of decks and bulkheads except as follows:

3. Where through cable runs within a compartment are easily traced (such as vertical run between decks), a single tag will suffice.

4. For cables with both points of connection within a compartment and which can be readily traced, a single tag will suffice.

5. Where compartments are subdivided by internal bulkheads or where machinery or installed equipment makes tracking of cable runs difficult, additional tags shall be provided.

6. For multiple cable penetrations of decks and bulkheads (main cableways), individual cable tags can be omitted, and in lieu thereof, an identification plate shall be installed adjacent to the cableway penetration area showing each cable designation in the order of location in the penetration area.

408–3.4.3 CABLE IDENTIFICATION. All fiber optic topology cables are marked with the letters FO, followed by a dash, the letter designating the service category, the circuit designation, and the fiber optic cable number. The circuit designations are as listed in Naval Ships' Technical Manual (NSTM) Chapter 079 Volume 2. If two or more circuits are installed that require identical designating letters, differentiating numbers in sequence beginning with 1 are used and precede the service category. An example follows:

FO–9C14TV010

9 is a circuit differentiating number which indicates the fiber optic cable is part of a circuit of which there are two or more identical designating letters.

C indicates interior communication service.

14TV indicates surveillance, training, and entertainment television system.

010 indicates this is the 10th fiber optic cable in the circuit or system.

408–3.4.3.1 The service category is identified in accordance with Table 408–3–5. Cables are numbered consecutively from 1 in each circuit or system, beginning at the unit where the optical signal is generated.

Table 408–3–5. SERVICE CATEGORY

Service Category	Identifying Letter
Electronic service	R
Fire control service	G
Interior communications service	C
Machinery control service	K

408–3.4.4 FIBER MARKINGS. All optical fibers are marked with the letter F, followed by a dash, the letter designating the service category, the circuit designation, the fiber optic cable number, a dash, and a unique number identifying the individual fiber within the cable. Fibers are consecutively numbered beginning with 101. The circuit designations are as listed in Naval Ships' Technical Manual (NSTM) Chapter 079 Volume 2. If two or more circuits are installed that require identical designating letters, differentiating numbers in sequence beginning with 1 are used and precede the service category. An example follows:

F–9C14TV010–101

9 is a circuit differentiating number which indicates the fiber optic cable is part of a circuit of which there are two or more identical designating letters.

C indicates interior communication service.

14TV indicates surveillance, training, and entertainment television system.

010 indicates this is the 10th fiber optic cable in the circuit or system.

101 indicates this is the 1st fiber in the cable.

408–3.4.4.1 The service category is identified in accordance with Table 408–3–5. Cables are numbered consecutively from 1 in each circuit or system, beginning at the unit where the optical signal is generated.

408–3.4.5 INTERCONNECTION BOX IDENTIFICATION PLATES. The identification plate on an IC box identifies it as fiber optic and gives the physical location of the box by using a basic location number. For example, FO 3–172–1 would identify a fiber optic IC box located on the third deck, starboard side, at the 172nd frame. If it is necessary to stack boxes in a vertical column, a suffix is used to distinguish between them (e.g. FO 3–172–1A and FO 3–172–1B).

NOTE

Warning labels are placed on interconnection boxes to indicate where optical hazards may be present.

408–3.5 FAULT ISOLATION

408–3.5.1 GENERAL. The following repair procedures reflect information from MIL–STD–2042(SH), **Fiber Optic Topology Installation Standard Methods for Naval Ships**. The above MIL–STD should be referred to for repair procedures questions that are not answered here.

NOTE

All changes in configuration which occur as a result of repairs shall be reported with OPNAV FORM 4790–2K as detailed in OPNAVINST 4790.4.

408–3.5.2 TYPES OF SIGNAL LOSS. When repairing optical cable one should remember that there are always signal losses when fibers are joined. However, understanding the major causes and possible solutions to coupling losses can help minimize them.

a. **End Separation –** Loss that is caused when the fibers are separated by a small gap. This type of loss can be reduced by using index matching gel between fiber ends (as in the rotary splice). Also, this type of loss can be reduced by using connectors in which the fibers are butted against one another (as in the physical contact ST connector). Spring pressure is also used to reduce such loss in ST connectors.

b. **Axial/Lateral Misalignment –** Loss that occurs when one fiber's axis is offset from that of the fiber to which it is spliced. This type of loss can occur when epoxy spills are not removed from the outside of the connector ferrule during the connector repair process.

c. **Angular Misalignment –** Loss occurring when the ends of the mated fibers are not perpendicular to fiber axes and perpendicular to each other during engagement. A properly polished connector and a high quality mating adapter controls this type of misalignment.

d. **Surface Finish Loss –** Loss caused by irregularities on the surface of a fiber face such as scratches, burrs and fractures that disrupt the light beam.

408–3.5.3 FAULT ISOLATION PROCEDURE. The following fault isolation procedure applies in general to all types of fiber optic links, not just those utilizing the fiber optic cable plant. The procedure assumes that only one fault is present in the link, but multiple faults could be identified during the process. If multiple faults are present and not identified initially, the process can be repeated until all of the faults are identified. The procedure is written in terms of a half duplex link, but can be applied to full duplex links as well. The procedure can be performed with one person, but is more efficient when performed with two people.

NOTE

System level or equipment level fault isolation procedures should be performed in accordance with the equipment or system technical manual before performing this procedure.

Step a – Activate the transmit equipment so that an optical signal is being transmitted. For some equipment links the transmit equipment will not transmit if the link is not connected to the system receiver. If this is the case, proceed to step d.

Step b – Measure the output optical power of the transmit interface.

1. Disconnect the equipment interface cable containing the transmit fiber. This may provide either a direct connection to a transmitter, or to a pigtail connector.

2. Connect a short jumper cable between the equipment interface and an OLTS detector (power meter). If the jumper cable is a multifiber cable make sure that the power meter is connected to the correct fiber in the jumper cable.

3. Measure and record the output optical power displayed on the optical power meter (dBm).

4. Compare the measured value to the equipment interface output power specification. If the output power is less than the minimum specified value, the transmit equipment is faulty. Refer to the equipment or system technical manual to find and replace the faulty equipment parts.

NOTE

If the transmit equipment is faulty, verify that the socket terminus in the equipment receptacle has not been pushed back out of its proper position.

5. If the output power is greater than or equal to the minimum specified value, the transmit equipment is not faulty. Reconnect all of the link connections and proceed to step c.

Step c – Check the optical power at the equipment receive interface.

1. Disconnect the equipment interface cable containing the receive fiber.

2. Connect a short jumper cable between the equipment interface cable and a power meter. If the jumper cable is a multifiber cable make sure that the power meter is connected to the correct fiber in the jumper cable.

3. Measure and record the link output optical power displayed on the optical power meter (dBm).

4. Compare the measured value to the equipment interface minimum input optical power specification. If the link output power is greater than or equal to the minimum specified value, the receive equipment is faulty. Refer to the equipment or system technical manual to find and replace the faulty equipment parts.

NOTE

If the receive equipment is faulty, verify that the socket terminus in the equipment receptacle has not been pushed back out of its proper position.

5. If the link output power is less than the minimum specified value, there is a fault in the fiber optic cable plant. Reconnect all of the link connections and proceed to step d.

Step d – Find a fault in a cable plant link using the Mini-OTDR (the cable plant link is checked out from the transmit equipment end).

1. Disconnect the equipment interface cable containing the transmit fiber.

2. Connect the dead zone fiber between the Mini-OTDR and the equipment interface cable containing the transmit fiber. If the interface cable is a multifiber cable, make sure that the Mini-OTDR is connected to the correct fiber in the interface cable.

3. Measure the link with the Mini-OTDR and compare the location and loss of each fault in the link with the installation data (see section 408–3.3.3.3).

4. If the Mini-OTDR will not measure the link, proceed to step f and check the input connector of the transmit equipment interface cable.

NOTE

Verify that the pin terminus in the equipment interface cable plug has not been pushed back out of its proper position.

5. If any faults are present that were not present at the time of installation, record the location of the nearest installed connection and the distance between the fault and the nearest installed connection and proceed to step e.

6. If the loss of any connection is higher than the allowable maximum value, identify and record the connection location and proceed to step f.

7. If no faults are present that were not present at installation and all connection losses are within specification, proceed to step f. and check the output connector of the receive equipment jumper cable.

Step e – Verify the fiber fault and isolate the fault location.

1. Go to the location of the connection installed nearest to the fiber fault.

2. Connect the dead zone fiber between the Mini-OTDR and the connector nearest the faulty fiber location.

3. If the Mini-OTDR will not measure the faulty fiber, proceed to step f.

4. If the Mini-OTDR will measure the faulty fiber, verify that the measurement still indicates that the fiber contains a fault. If it does not, return to step c.

5. If the fiber does contain a fault, connect the light source of the optical leak detector (OLD) to the faulty fiber with a short jumper. If the jumper cable is a multifiber cable make sure that the OLD is connected to the correct fiber in the jumper cable. (The OLD is a test instrument used to physically locate fiber breaks or high loss regions in an optical fiber or an OFCC of a multi-fiber cable.)

6. Follow the cable along its installed path and using the fault distance measured with the Mini-OTDR, estimate the approximate location of the fiber fault.

7. Visually inspect the cable beginning at the estimated location of the fault and gradually inspecting the cable in both directions outward from the estimated fault location. Conditions that may indicate the fault locations are jacket tears and cuts, pinched cable, severely bent cable, burned cable, or cable exhibiting excessive slack length due to being used as a handhold.

8. When a physical location for the fault is identified, remove the outer cable jacket over approximately 6 to 12 inches of the cable (in some cases it may be necessary to remove more cable jacket, but this should only be done if the fiber fault location is not found after the first removal).

9. Using the OLD, identify the location of the fiber fault. Then, follow the maintenance procedures identified in Maintenance Procedures.

Step f – Identify a faulty connection or a fiber fault near a connection.

1. Visually inspect the entire connection for damage and select one plug or receptacle for initial inspection. Conditions that may indicate connector or fiber damage are broken or deformed connector shells, backshells, strain reliefs, or ferrules; burned connector parts; cable movement into or out of the connector backshell or strain relief; and visible cable strength members at the back of the cable strain relief.

2. Visually inspect the ferrule endface of the possibly faulty connection.

3. If the ferrule endface is dirty, clean the endface with a soft cloth and alcohol.

4. Connect the dead zone fiber between the Mini-OTDR and the chosen connector (if the connection is a multifiber connector connect the dead zone fiber between the Mini-OTDR and the correct terminus of the connector).

5. If the Mini-OTDR will measure the link, repeat step e for the other half of the connection.

6. If the Mini-OTDR will not measure the link, connect the light source of the OLD to the chosen connector with a short jumper cable (if the connector is a multifiber connector make sure that the OLD is connected to the correct fiber in the jumper cable).

7. Using the OLD, find the location of the fiber fault (if the connection is a multifiber connector, remove the connector backshell before using the optical leak detector). Then, follow the maintenance procedures identified in Maintenance Procedures.

408–3.6 MAINTENANCE PROCEDURES

408–3.6.1 GENERAL. Detailed instructions on maintenance procedures may be given in the system technical manual. If no instructions are found in the system technical manual, the following general maintenance procedures may be utilized to repair a faulty link.

408–3.6.2 SPARE FIBERS. The first option for the repair of a faulty fiber optic link is to replace the faulty fiber assembly with a spare fiber assembly in the same cable. Spare fibers are provided in all cables that penetrate decks or bulkheads. The use of the spare fibers requires a change in the configuration of the connectors on the connector patch panels, or of the termini in multifiber connector inserts, at each end of the faulty fiber assembly. These configuration changes shall be reported with OPNAV FORM 4790–2K as detailed in OPNAVINST 4790.4.

408–3.6.3 REDUNDANT CABLES. The second option for the repair of a faulty fiber optic link is to replace the faulty cable assembly with an installed redundant cable assembly. Redundant cable assemblies are provided for extremely critical cable assemblies in some ship designs. The use of a redundant cable also requires a change in the configuration of the connectors on the connector patch panels, or of the termini in multifiber connector inserts, at each end of the faulty cable assembly. These configuration changes shall be reported with OPNAV FORM 4790–2K as detailed in OPNAVINST 4790.4.

NOTE

Redundant cables should only be used as a temporary repair. The connection within the faulty fiber assembly should be repaired or the cable assembly replaced at the earliest opportunity.

408–3.6.4 GROWTH FIBERS. The third option for the repair of a faulty fiber optic link is to replace the faulty fiber assembly with a growth fiber assembly in the same cable. Growth fibers may be provided in some cables within the topology (such as trunk cables). The use of the growth fibers requires a change in the configuration of the connectors on the connector patch panels, or of the termini in multifiber connector inserts, at each end of the faulty fiber assembly. These configuration changes shall be reported with OPNAV FORM 4790–2K as detailed in OPNAVINST 4790.4.

NOTE

Growth fibers should only be used as a temporary repair. The connection within the faulty fiber assembly should be repaired or the cable assembly replaced at the earliest opportunity.

408–3.7 COMPONENT REPAIR

408–3.7.1 GENERAL. The fourth option for the repair of a faulty fiber optic link is to repair, replace, or restore the faulty fiber optic component. Fiber optic connectors and splices can be repaired or replaced. Fiber optic cables can be restored.

408–3.7.2 CABLE RESTORATION. The restoration of a faulty cable requires the temporary installation of one or two mini-interconnection boxes within the cableway and the completion of connector terminations at the fault location. Refer to the procedures contained in Cable Restoration Procedure.

NOTE

Cable restoration should only be used as a temporary repair. The cable assembly should replaced at the earliest opportunity.

408–3.8 REPAIR PROCEDURES

408–3.8.1 GENERAL. Refer to the specific procedures contained in Cable Restoration, Single Fiber Rotary Splice Ferrule Installation, Single Fiber Termination Connection Procedure, and Multiple Fiber Connector Repair.

408–3.8.2 CABLE RESTORATION PROCEDURE. This section describes the procedure for using a cable restoration kit (NAVSEA DRAWING 6877992) to temporarily restore a faulty fiber optic cable.

408–3.8.2.1 Safety. The following safety precautions shall be observed:

a. Do not touch the ends of the fiber. Wash your hands thoroughly after handling bare fibers.

b. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

408–3.8.2.2 Restoration Procedure

Step a – Cut out the damaged section of the cable using wire cutters or kevlar shears.

Step b – Find a mounting location for the mini-interconnection box which is accessible to both ends of the damaged cable. If both ends of the damaged cable will not reach a single box, find mounting locations for two mini-interconnection boxes (one box for each cable end).

Step c – Mount the mini-interconnection boxes at the chosen mounting locations. Proceed to step d if only one box was required. Proceed to step e if two boxes were required.

NOTE

> The mini-interconnection box should be securely mounted using M9.53 x 1.59 (3/8–16) bolts to avoid any safety hazards to personnel.

Step d – Install both cables into the box using the procedures contained in Equipment Cable Entry By Way of Nylon Stuffing Tubes. Proceed to step f.

Step e – Install both cables and a bridging cable into the boxes using the procedures contained in Equipment Cable Entry By Way of Nylon Stuffing Tubes.

Step f – Install MIL–C–83522/16 ST type connectors on the cable OFCCs using the procedures contained in Single Fiber Termination Connection Procedure.

408–3.8.3 CABLE AND JACKET REPAIR. This section describes procedures for repairing the damaged outer jacket of a cable with kevlar strength members intact.

408–3.8.3.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn when handling bare fibers.

2. Do not touch the ends of the fiber as they may be razor sharp. Wash your hands after handling bare fiber.

3. Observe warnings and cautions on equipment and materials.

4. Never stare into the end of a fiber connected to a laser source or LED.

408–3.8.3.2 METHOD 1: Wraparound Sleeve with Rail Closure. The equipment and materials in Table 408–C–2 (Appendix C) shall be used to perform this procedure.

Step a – Select a repair sleeve in accordance with Table 408–C–2 (Appendix C).

Step b – Trim off the frayed, burned, or protruding jacket material with a knife using care not to damage the kevlar or OFCC jacket (see Figure 408–3–11). Square up the jacketing where required.

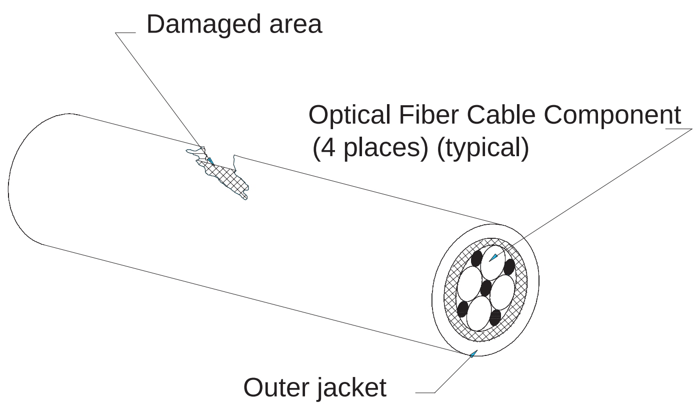

Figure 408–3–11. Damaged Cable

Step c – Abrade the jacket circumferentially to the dimension shown using emery cloth or a fine file (see Table 408–C–2 in Appendix C and Figure 408–3–12.

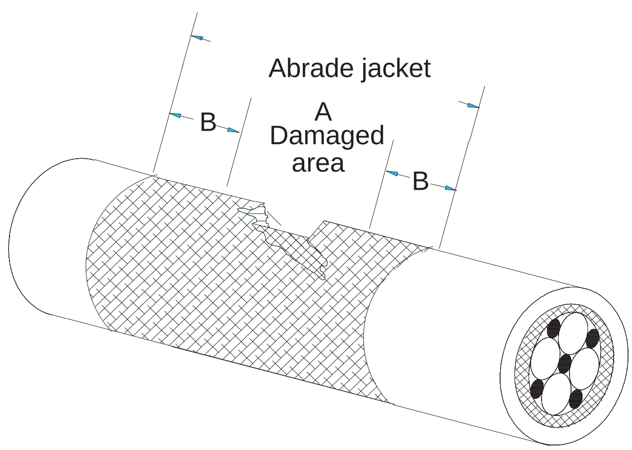

Figure 408–3–12. Cable Preparation

Step d – Clean the abraded area with a wipe dampened with alcohol, and blow dry with air.

Step e – Fill any large depressions or voids with tape, as required, to restore the cable contour as follows:

WARNING

Application of too much heat will cause the adhesive to flow and may cause burns if it comes in contact with the skin.

1. Cut off short strips of the adhesive tape and heat them slightly with the heat gun to soften them.

2. Roll the tape with your fingers and press it into the damaged area. Repeat the process until the damaged area is filled.

3. Holding the heat gun approximately 102 mm (4 inches) away, apply just enough heat to the tape to form and contour the tape to the cable (see Figure 408–3–13).

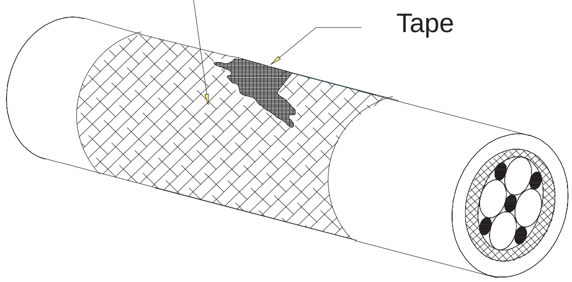

Figure 408–3–13. Tape Contoured to Cable

Step f – Cut the cable jacket repair sleeve to the proper length (see Table 408–C–2 in Appendix C).

CAUTION

Do not overheat the cable. The jacket should be just warm to the touch. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket.

Step g – Hold the heat gun approximately 102 mm (4 inches) away from the cable and apply heat to all parts of the cable jacket to which the repair sleeve is to be applied.

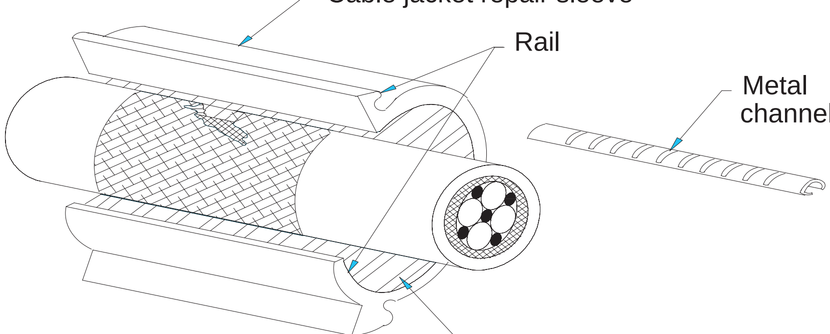

Figure 408–3–14. Installing Sleeve

Step h – Assemble the repair sleeve as shown (see Figure 408–3–14). Leave approximately 13 mm (0.5 inch) overhang of channel on both sides of sleeve (see Figure 408–3–15).

CAUTION

Do not overheat the cable. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket. Discontinue heating of the sleeve and allow the cable jacket to cool before reheating if the cable jacket shows any signs of bubbling.

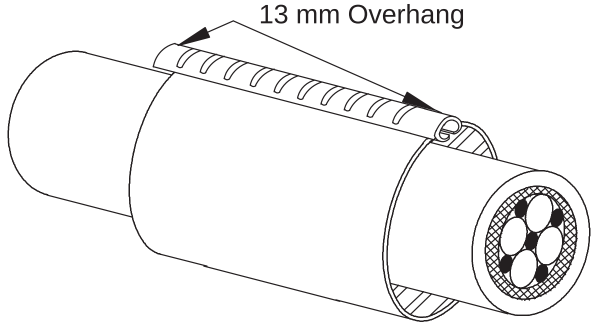

Figure 408−3−15. Assembled Sleeve

Step i – Center the sleeve over the damaged area and, holding the heat gun approximately 102 mm (4 inches) away, heat evenly from the center to the ends around the entire sleeve until the sleeve changes color indicating a full recovery (see Figure 408–3–16). Melted sealant should be visible at the end of sleeve.

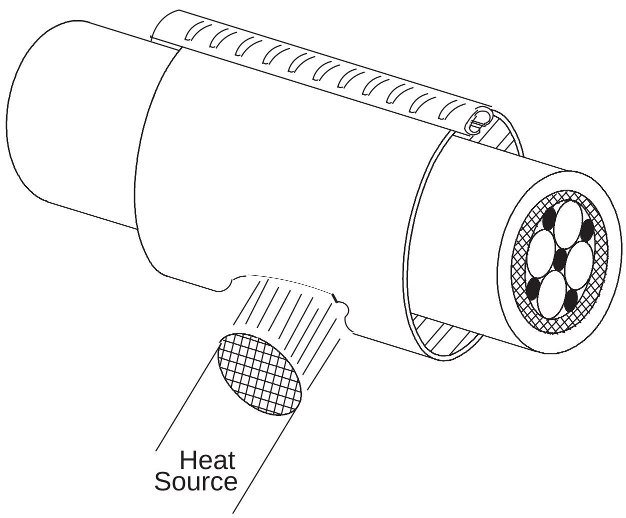

Figure 408−3−16. Shrinking Sleeve

Step j – When the sleeve has cooled, the rail and metal channel may be trimmed from the sleeve to provide greater flexibility to the cable (see Figure 408–3–17).

408–3.8.3.3 METHOD 2: Tube Sleeve. The equipment and materials in Table 408–C–1 (Appendix C) shall be used to perform this procedure.

Step a – Select repair sleeve in accordance with Table 408–C–3 (Appendix C).

Step b – Trim off the frayed, burned, or protruding jacket material with a knife using care not to damage the kevlar or OFCC jacket (see Figure 408–3–18). Square up the jacketing where required.

Step c – Abrade the jacket circumferentially to the dimension shown using emery cloth or a fine file (see Table 408–C–3 and Figure 408–3–19).

Step d – Clean the abraded area with alcohol and blow dry with air.

Step e – Fill any large depressions or voids with tape, as required, to restore the cable contour as follows:

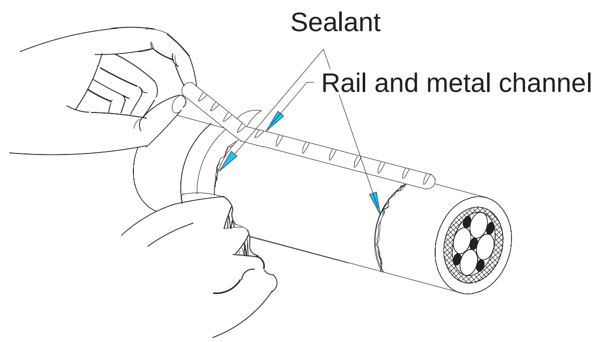

Figure 408−3−17. Trimming Rails and Metal Channel

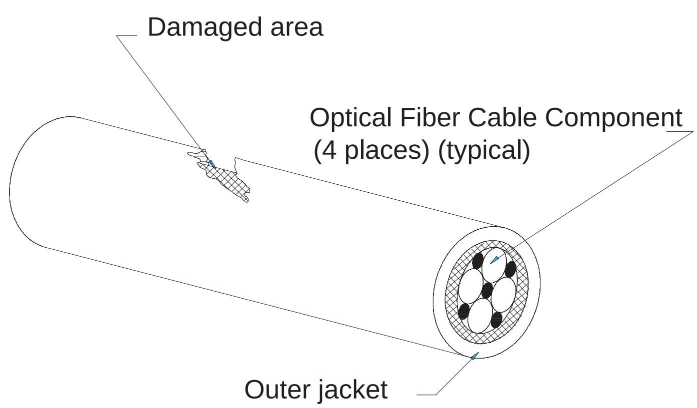

Figure 408−3−18. Damaged Cable

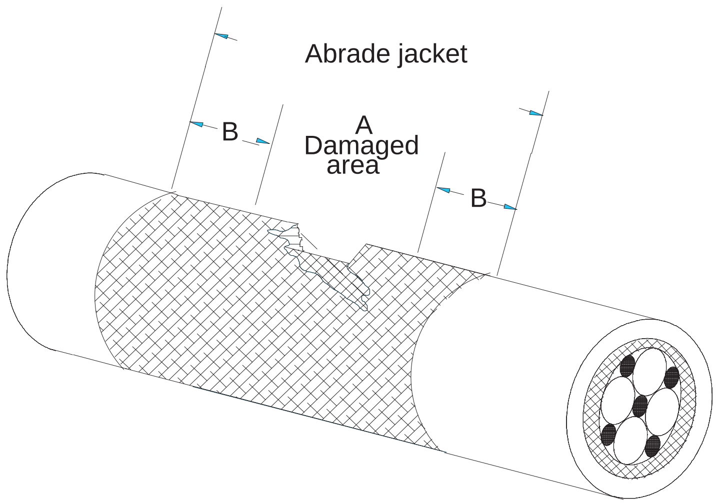

Figure 408−3−19. Cable Preparation

WARNING

Application of too much heat will cause the adhesive to flow and may cause burns if it comes in contact with the skin.

1. Cut off short strips of the adhesive tape and heat them slightly with the heat gun to soften them.

2. Roll the tape with your fingers and press it into the damaged area. Repeat the process until the damaged area is filled.

3. Holding the heat gun approximately 102 mm (4 inches) away, apply just enough heat to the tape to form and contour to the cable (see Figure 408–3–20).

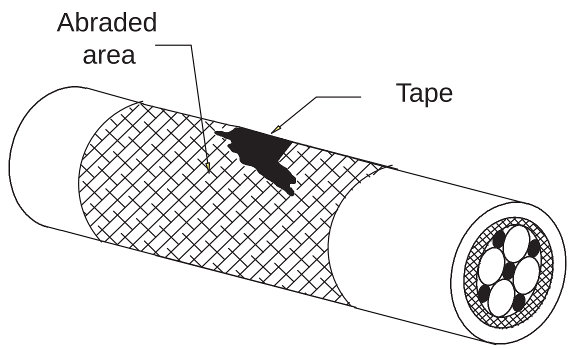

Figure 408–3–20. Tape Contoured to Cable

Step f – Cut the cable jacket repair sleeve to the proper length (see Table 408–C–3 in Appendix C).

CAUTION

Do not overheat the cable. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket. Discontinue heating of the sleeve and allow the cable jacket to cool before reheating if the cable jacket shows any signs of bubbling.

Step g – Center the repair sleeve over the damaged area. Hold the heat gun approximately 102 mm (4 inches) away and heat the center by applying heat evenly around the sleeve until it shrinks over cable (see Figure 408–3–21). Working towards one end, shrink the sleeve to the cable until sealant is flowing at end of the sleeve. Repeat the procedure on the other half of the sleeve (see Figure 408–3–22).

Step h – Remove heat and allow the sleeve to cool.

408–3.8.3.4 METHOD 3: Rubber Tape. The equipment and materials in Table 408–C–4 (Appendix C) shall be used to perform this procedure.

Step a – Trim off any frayed, burned, or protruding jacket material with a knife using care not to damage the kevlar or the OFCC jacket (see Figure 408–3–23). Square up the jacketing where required.

Step b – Abrade the jacket circumferentially approximately 76 mm (3 inches) on either side of the damaged area using emery cloth or a fine file (see Figure 408–3–24).

Step c – Clean the abraded area with alcohol and blow dry with air.

Step d – Fill any large depressions or voids with adhesive tape as required to restore the cable contour as follows:

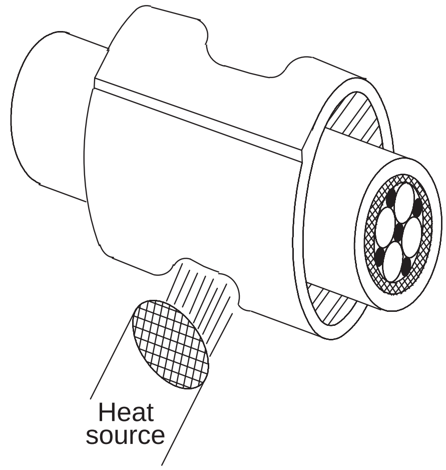

Figure 408−3−21. Shrinking the Sleeve

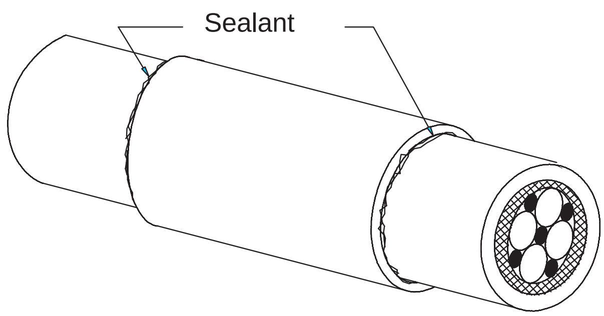

Figure 408−3−22. Completed Repair

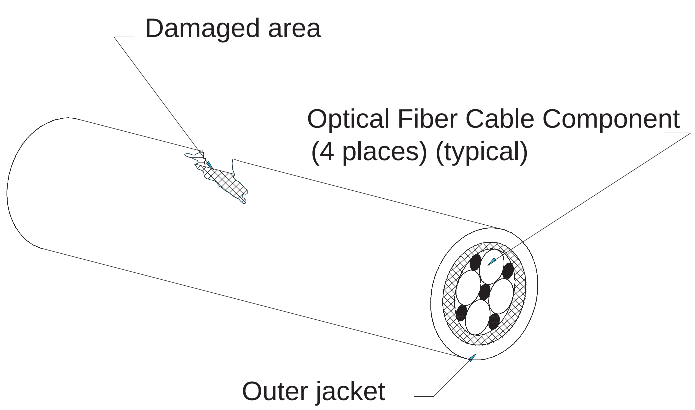

Figure 408−3−23. Damaged Cable

WARNING

Application of too much heat will cause the adhesive to flow and may cause burns if it comes in contact with the skin.

1. Cut off short strips of adhesive tape and heat them slightly with the heat gun to soften them.

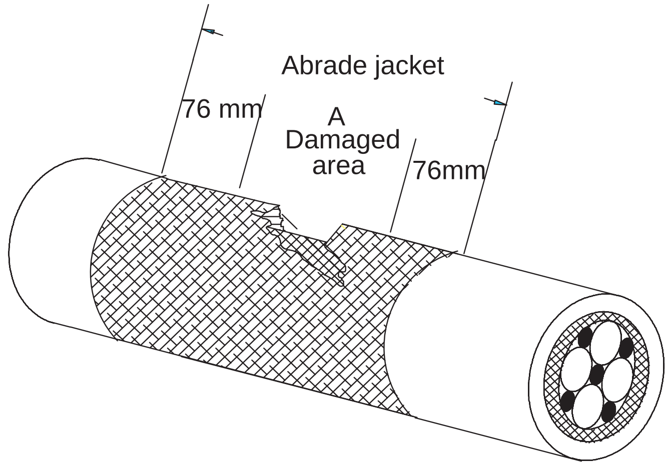

Figure 408–3–24. Cable Preparation

2. Roll the tape with your fingers and press them into the damaged area. Repeat process until the damaged area is filled.

3. Holding the heat gun approximately 102 mm (4 inches) away, apply just enough heat to the tape to form and contour to the cable (see Figure 408–3–25).

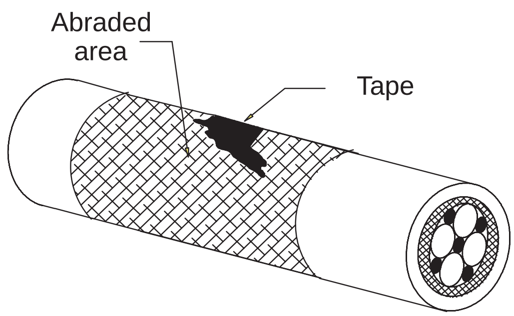

Figure 408–3–25. Tape Contoured to Cable

Step e – Cover the entire abraded area with one layer of half lapped adhesive and sealant tape, pulling the tape to approximately one-half its original thickness.

Step f – Cover the adhesive and sealant tape with one layer of half lapped fiberglass tape.

CAUTION

Do not over heat the cable. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket. Discontinue heating of the tape and allow the cable jacket to cool before reheating if the cable jacket shows any signs of bubbling.

Step g – Holding the heat gun approximately 102 mm (4 inches) away from the cable, heat the entire area covered by the tape for approximately 3.5 minutes with the heat gun to blend the adhesive and sealant into the fiberglass tape.

Step h – Apply a coat of electrical coating to the entire area and let it set a minimum of 10 minutes.

408–3.8.3.5 METHOD 4: Wraparound Sleeve With Adhesive Closure. The equipment and materials in Table 408–C–1 (Appendix C) shall be used to perform this procedure.

Step a – Select a repair sleeve in accordance with Table 408–C–5 (Appendix C).

Step b – Trim off any frayed, burned, or protruding jacket material with a knife using care not to damage the kevlar or the OFCC jacket (see Figure 408–3–26). Square up the jacketing where required.

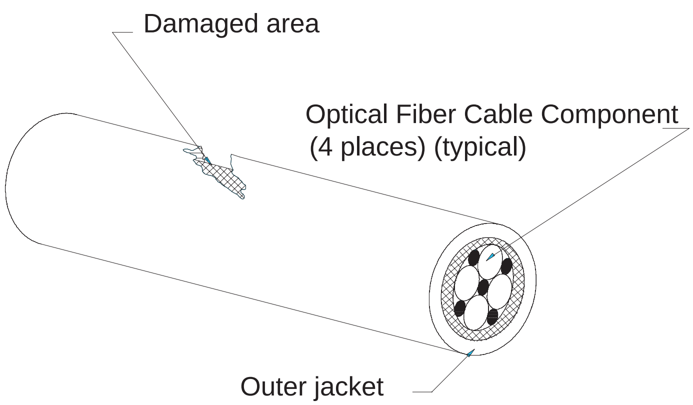

Figure 408–3–26. Damaged Cable

Step c – Abrade the jacket circumferentially to the dimension shown using emery cloth or a fine file (see Figure 408–3–27).

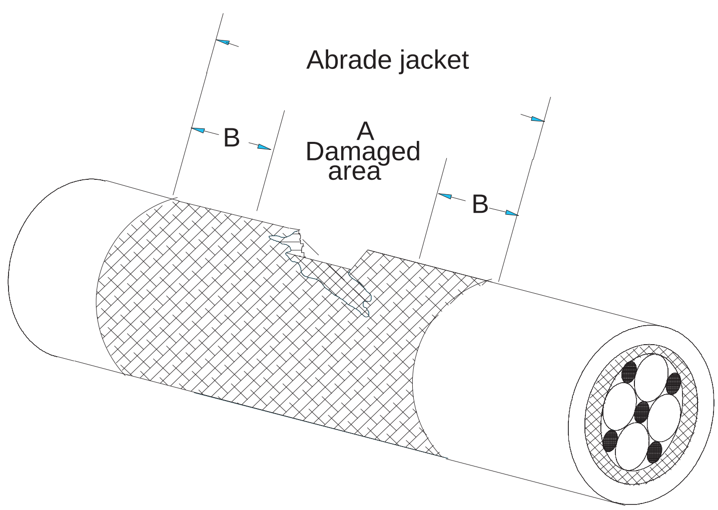

Figure 408–3–27. Cable Preparation

Step d – Clean the abraded area with alcohol and blow dry with air.

Step e – Fill any large depressions or voids with adhesive tape as required to restore the cable contour as follows:

WARNING

Application of too much heat will cause the adhesive to flow and may cause burns if it comes in contact with the skin.

1. Cut off short strips of adhesive tape and heat them slightly with the heat gun to soften them.

2. Roll the tape with your fingers and press them into the damaged area. Repeat process until the damaged area is filled.

3. Holding the heat gun approximately 102 mm (4 inches) away, apply just enough heat to the tape to form and contour to the cable (see Figure 408–3–28).

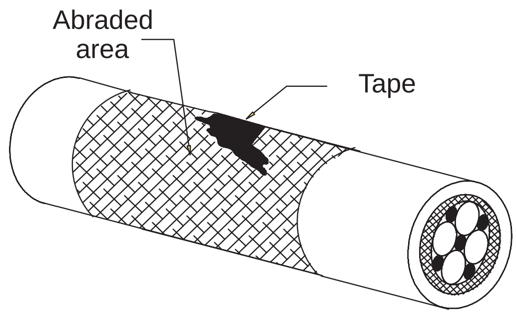

Figure 408–3–28. Tape Contoured to Cable

Step f – Cut the cable jacket repair sleeve to the proper length (see Table 408–C–5 in Appendix C).

CAUTION

Do not overheat the cable. The jacket should be just warm to the touch. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket.

Step g – Hold the heat gun approximately 102 mm (4 inches) away from the cable and apply heat to all parts of the cable jacket to which the repair sleeve is to be applied.

Step h – Remove the protective release tape from both flaps of the sleeve to expose the surfaces of the contact adhesive.

Step i – Place the sleeve around the cable so that the sealant side of the sleeve is next to the cable, align the sleeve side edges, and press the contact surfaces together along the full length of the sleeve (see Figure 408–3–29).

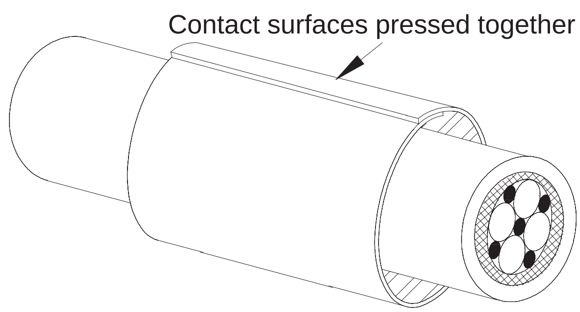

Figure 408–3–29. Assembled Sleeve

CAUTION

Do not over heat the cable. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket. Discontinue heating of the tape and allow the cable jacket to cool before reheating if the cable jacket shows any signs of bubbling.

Step j – Center the repair sleeve over the damaged area. Hold the heat gun approximately 102 mm (4 inches) away and heat the center by applying heat evenly around the sleeve until it shrinks over cable (see Figure 408–3–30). Working towards one end, shrink the sleeve to the cable until sealant is flowing at end of the sleeve. Repeat the procedure on the other half of the sleeve (see Figure 408–3–31).

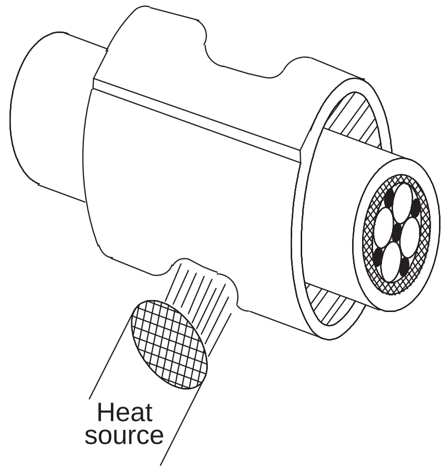

Figure 408–3–30. Shrinking Sleeve

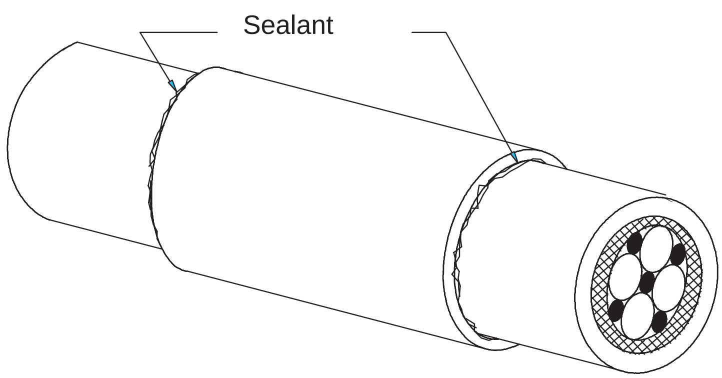

Figure 408–3–31. Completed Repair

Step k – Remove heat and allow the sleeve to cool.

408–3.8.4 SINGLE FIBER ROTARY SPLICE FERRULE INSTALLATION. The U.S. Navy uses the MIL–S–24623/4 rotary mechanical splice. The MIL–S–24623/4 splice is a commercial based fiber splice commonly called a rotary mechanical splice. However, all commercial rotary mechanical splices are **not** compatible with the MIL–S–24623/4 splice. Only commercial rotary mechanical splices with ferrule diameters between 2.4996 mm and 2.5006 mm (AT&T letter code “M”) are compatible with the MIL–S–24623/4 splice. Fusion splicing, where the fiber ends are melted together, is not currently used in the Navy. This section describes the procedure for installing a MIL–S–24623/4 splice ferrule onto an optical fiber. The equipment and materials in Table 408–C–6 (Appendix C) as applicable shall be used to perform this procedure.

408–3.8.4.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers or dispensing adhesive.

2. Do not touch the ends of the fiber. Wash your hands thoroughly after handling bare fibers.

3. Avoid skin contact with adhesives.

4. Do not look into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

5. Ultraviolet (UV) safety glasses shall be worn when using the UV curing lamp.

408–3.8.4.2 Cable and Fiber Preparation

CAUTION

Throughout the termination process, cleanliness is critical to obtaining a high optical quality splice. Make sure your hands and the work area are as clean as possible to minimize the ingress of dirt into the splice.

NOTE

Keep the OFCCs and splice parts free from oil, dirt and grease throughout the installation procedure. If cleaning is necessary, use a wipe dampened with alcohol and blow the part dry with air.

Step a – Measure the OFCCs to the required length (refer to the procedures in Cable Entry for measuring and stripping back the appropriate length of cable jacket). Then add sufficient slack to allow for at least two reterminations [40 mm (1.60 inches) of slack should be sufficient for one retermination].

Step b – Slip the heat shrink tubing with the fiber identification over the OFCC.

Step c – Measure the distance from the expected splice position in the splice tray to the last OFCC tie down location, add approximately 60 mm (2.4 inches) and mark the OFCC jacket. Using the OFCC stripper, remove the OFCC jacket back to the mark.

Step d – Separate the kevlar strands from the buffered fiber and, using the kevlar shears, trim the strands back to the OFCC jacket edge.

WARNING

Wear safety glasses when removing the fiber buffer and coating to avoid possible eye injury.

Step e – Mark the fiber buffer 30 mm (1.20 in) back from the end of the fiber, and remove the fiber buffer and coating back to the mark using the buffer stripper. Remove the buffer and coating in small sections (approximately 6 mm (0.25 in) at a time.)

NOTE

Normally, the buffer and coating are tightly adhered to one another and come off of the fiber at the same time.

CAUTION

The uncoated fiber is in its most vulnerable state. Take extreme care not to damage the fiber.

Step f – Remove any residual coating material from the bare fiber with a wipe dampened with alcohol. Wipe only once from the end of the buffer towards the end of the fiber.

NOTE

Do not repeatedly wipe the bare fiber as this will weaken the fiber.

408–3.8.4.3 Installation of Ferrules onto Fibers

Step a – Separate the ferrules by grasping both sides of an assembled ferrule pair with the thumb and index fingers. Simultaneously pull and slightly bend the ferrules until they separate. (If the ferrules are already separated and matching ferrule sets are not obvious, inspect the ferrules to verify that all of the ferrules are MIL–S–24623/4 ferrules. Unmatched ferrules can be mated with no reduction in optical performance only if the ferrules are MIL–S–24623/4.)

NOTE

Do not twist the ferrules during separation.

Step b – Install the syringe tip on the UV adhesive syringe.

NOTE

Verify that the adhesive and index matching material shelf life has not expired. Do not use adhesive or index matching material with an expiration date that has passed.

Step c – Cover the entire ferrule assembly with a UV blocking shield if the splicing procedure will be performed in direct or bright sunlight or under bright fluorescent lamps.

NOTE

Normal ship lighting is not bright enough to cause the UV adhesive to cure prematurely.

WARNING

Wear safety glasses when dispensing epoxy to avoid possible eye injury.

Step d – Insert the tip of the syringe into rear of the splice ferrule until the syringe tip bottoms out. Slowly inject adhesive into the ferrule until a very small bead appears on the ferrule tip (see Figure 408–3–32).

NOTE

Be extremely careful not to get adhesive on the splice spring or other splice moving parts.

Step e – Withdraw the syringe from the splice. Maintain some pressure on the plunger as the syringe is withdrawn so that the splice is completely filled with adhesive. Using a wipe dampened with alcohol, wipe away any adhesive on the outer diameter of the ferrule without disturbing the ferrule end. Place the syringe under a UV blocking shield or wipe.

Step f – Carefully insert the stripped fiber into the ferrule until the buffer bottoms out (see Figure 408–3–33). Once inserted, do not allow the fiber to slip back.

Step g – Verify that there is a small amount of adhesive around the fiber where it protrudes from the ferrule. If it is found that there is no small bead of adhesive on the ferrule tip, carefully add a small amount of adhesive around the fiber.

NOTE

There should only be a small amount of adhesive around the fiber to support it later during the polishing process.

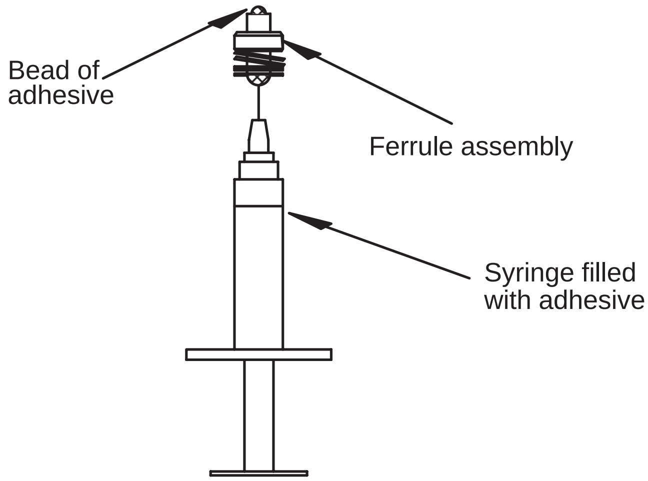

Figure 408–3–32. Injecting Adhesive into the Ferrule

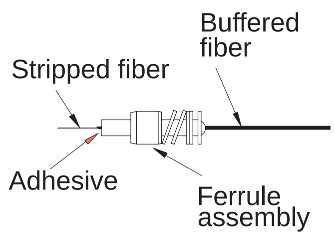

Figure 408–3–33. Inserting the Fiber into the Ferrule

Step h – Using a wipe dampened with alcohol, carefully wipe away any adhesive on the fiber that is more than 2 mm (0.08 in) from the ferrule surface.

408–3.8.5 CURING THE ADHESIVE

Step a – Remove the UV blocking shield, if it was used.

Step b – Place the prepared ferrule on the curing lamp base. Position the UV curing lamp over the ferrule (see Figure 408–3–34). Do not allow the ferrule to slide forward off of the fiber buffer.

NOTE

If possible, tape the OFCC's and the buffered fiber to any available surface during the curing period to avoid accidentally pulling the fibers out of the ferrules or the ferrules out from under the curing lamp.

WARNING

Wear UV safety glasses when using the curing lamp to avoid possible eye injury.

Step c – Turn on the curing lamp and cure the ferrules for a minimum of 2 minutes (maximum of 7 minutes).

Step d – Turn off the curing lamp and lift it off the curing lamp base. Remove the cured ferrules from curing lamp base.

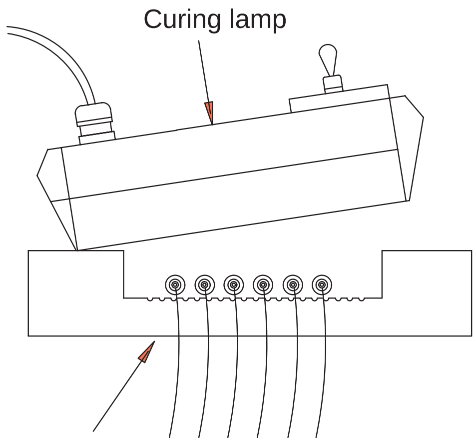

Figure 408−3−34. Positioning the Curing Lamp

WARNING

Wear safety glasses when scoring the fiber to avoid possible eye injury.

Step e – Score the fiber close to the ferrule tip at the epoxy interface using one short light stroke with cleaving tool (see Figure 408–3–35).

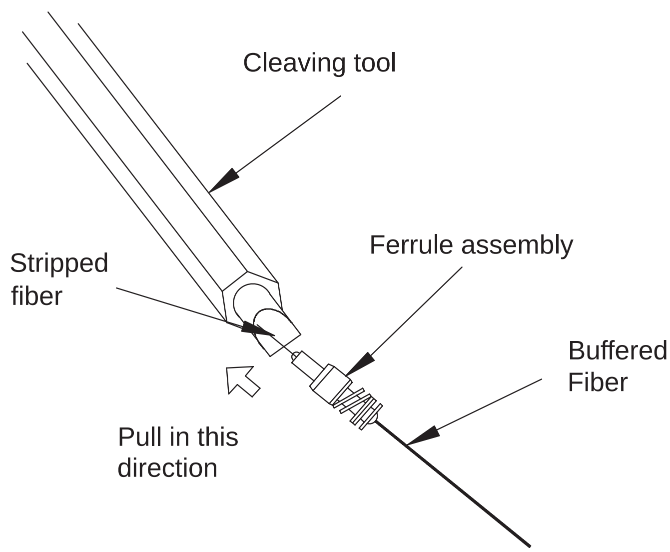

Figure 408−3−35. Scoring the Fiber

NOTE

Do not break the fiber with the cleaving tool.

Step f – Pull off the fiber with a gentle, straight pull. Deposit the waste fiber in a trash container.

Step g – Remove any adhesive on the cylindrical surface of the ferrule using a utility knife. Move the knife from the back to the front of the ferrule using a light force and a shallow working angle (see Figure 408–3–36).

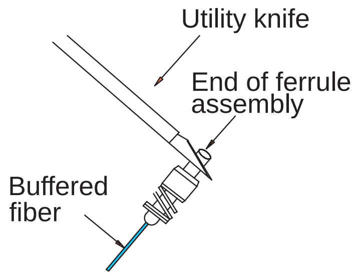

Figure 408−3−36. Removing the Excess Adhesive

NOTE

Be careful not to scratch the ferrule end.

Step h – Proceed to paragraph 408–3.8.5.1.

408–3.8.5.1 Polishing the Fiber Ends. Hand polishing is the preferred method of polishing ferrules. Only procedures for hand polishing are contained herein.

Step a – Clean the glass polishing plate, the backs of the polishing papers, and the surface of the polishing tool using a wipe dampened with alcohol. Blow all of the surfaces dry with air.

Step b – Insert the ferrule into the polishing tool.

Step c – Place the 8 μm polishing paper on the glass plate. Wet the paper and start polishing the ferrule with very light pressure (the weight of the tool) using a figure–8 motion (see Figure 408–3–37). Polish the ferrule until the adhesive is gone and the ferrule surface is unmarked. Since the polishing time varies with the amount of adhesive present on the tip of the ferrule, inspect the ferrule tip frequently using the eye loupe. Whenever the polishing tool is lifted, remove the grit from the tool and the ferrule with air.

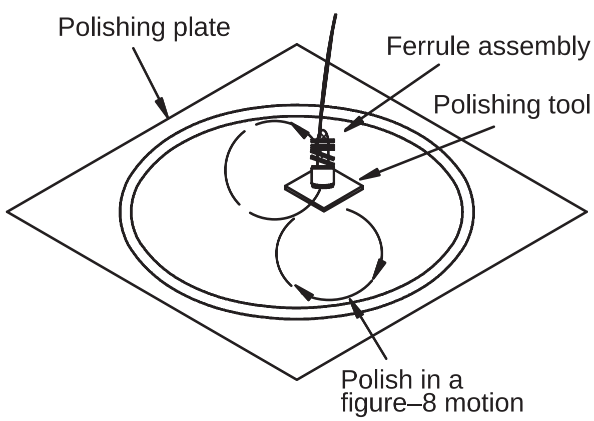

Figure 408−3−37. Polishing the Ferrule

Step d – Replace the 8 μm paper with the 0.3 μm paper. Wet the paper and polish the connector with very light pressure using a figure–8 motion for 5 to 10 complete motions.

NOTE

Do not over polish; 10 figure–8’s should be adequate.

Step e – Remove the ferrule from the tool and clean both with a wipe dampened with alcohol and blow dry with air.

Step f – Proceed to paragraph 408–3.8.6.

408–3.8.5.2 Quality Check

Step a – Examine the ferrule with the eye loupe to ensure that the optical surface is smooth and free of scratches, pits, chips, and fractures (see Figure 408–3–38). If any defects are present, repeat steps 408–3.8.5.1 a, b, d and e or reterminate the fiber.

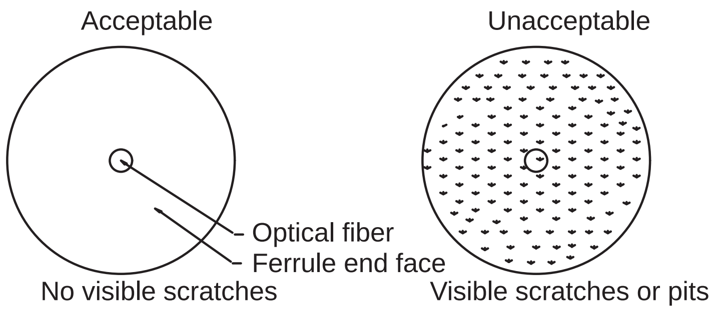

Figure 408–3–38. Quality Check

NOTE

Overpolishing the fiber will increase the optical loss of the splice. Do not polish the ferrule more than necessary to pass the quality check.

Step b – If the splice is not to be immediately mated in an alignment clip, install a plastic protective cap over the splice ferrule.

408–3.8.6 SINGLE FIBER ROTARY SPLICE WITHIN AN INTERCONNECTION BOX. This section describes a procedure for mating and aligning optical fibers terminated with DOD–S–24623/4 splice ferrules.

408–3.8.6.1 Splice Assembly Procedure

Step a – Mix a small portion of the index matching gel on a clean surface according to the manufacturer’s instructions provided (vacuuming is not required).

NOTE

The index matching gel provided may be a one part gel that does not require mixing.

CAUTION

Opening the sleeve too much may damage the sleeve.

Step b – Adjust the splice alignment clip tool so that it opens the splice alignment clip just enough to insert the splice ferrules. Insert the tool tip into the alignment sleeve slot. Open the sleeve (see Figure 408–3–39).

Step c – Dip one of the polished ferrule tips into the gel and slide the ferrule into the alignment clip until the tip is approximately centered in the clip (see Figure 408–3–40).

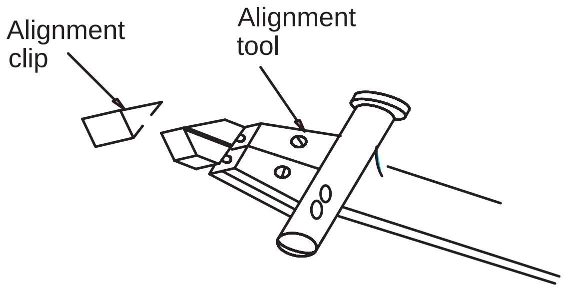

Figure 408–3–39. Opening the Alignment Sleeve

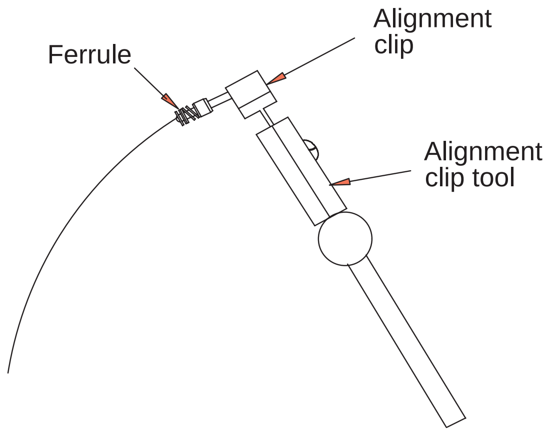

Figure 408–3–40. Inserting Ferrule into Alignment Sleeve

Step d – Dip the other ferrule tip into the index matching gel and slide the ferrule tip into the other side of the alignment clip (see Figure 408–3–41). Ensure that the ferrule tips are centered in the alignment clip and the alignment tabs are facing the clip gap. Remove the alignment clip tool from the alignment clip. Verify that the ferrule tips are in contact by pushing the ferrules together.

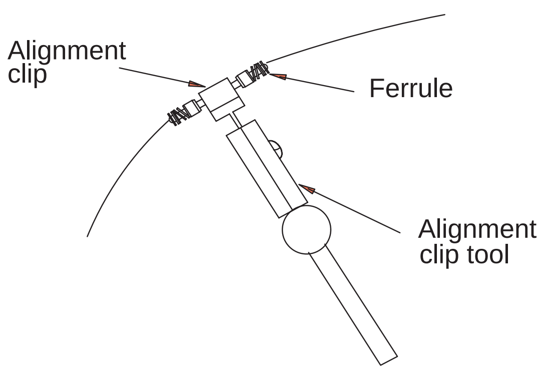

Figure 408–3–41. Inserting Second Ferrule into Alignment Sleeve

408–3.8.6.2 Splice Alignment. Perform a passive alignment or an active alignment, as appropriate.

NOTE

Passive alignment is sufficient in most cases. Active alignment shall be performed only when specified.

408–3.8.6.2.1 Passive Alignment

Step a – Verify the tab alignment by inserting the splice assembly into the splice alignment tool making sure the tabs fit into the tool slots (see Figure 408–3–42). If necessary, rotate either ferrule slightly to align the tabs. Remove the splice from the tool.

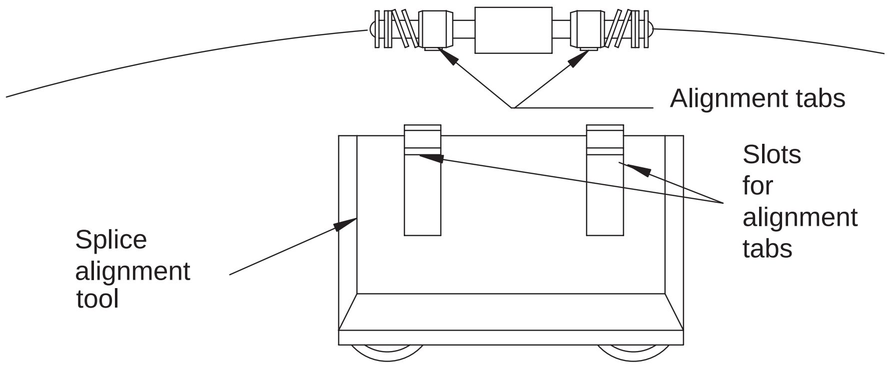

Figure 408–3–42. Aligning Tabs

408–3.8.6.2.2 Active Alignment

WARNING

Do not stare into the end of a fiber connected to an LED or laser diode. Light may not be visible but can still damage the eye.

Step a – Using the appropriate test adapters or test jumper cables, connect the cable ends opposite the splice ferrules of the cable under test to the light source and detector of two optical loss test sets and energize both (see Figure 408–3–43).

NOTE

Both optical loss test sets should be allowed to warm up before starting the active alignment so that the readings are stable.

Step b – Rotate the ferrules relative to each other until the maximum power is recorded at the optical detector. De-energize the optical loss test sets.

408–3.8.7 SINGLE FIBER CONNECTOR TERMINATION PROCEDURE. This section describes the procedure for installing MIL–C–83522/16 single terminus connectors onto fiber optic cable. The equipment and materials in Table 408–C–8 (Appendix C) shall be used to perform this procedure.

408–3.8.7.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers or dispensing epoxy.

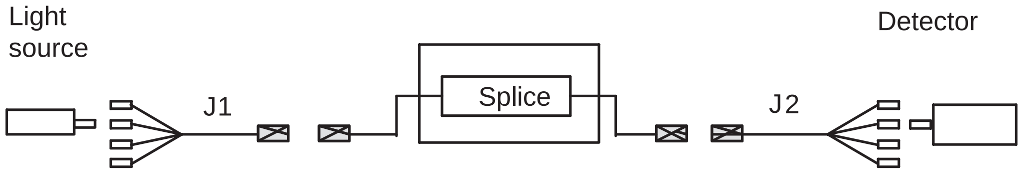

Figure 408–3–43. Active Splice Alignment Cable Hookup

2. Do not touch the ends of the fiber as they may be razor sharp. Wash your hands after handling bare fiber.

3. Avoid skin contact with epoxies.

4. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

408–3.8.7.2 Cable and Fiber Preparation

CAUTION

Throughout the termination process, cleanliness is critical to obtaining a high optical quality connector. Make sure that your hands and the work area are as clean as possible to minimize the ingress of dirt into the connector parts.

NOTE

Keep the OFCCs and connector parts free from oil, dirt and grease throughout the installation procedure. If cleaning is necessary, use a wipe dampened with alcohol and blow the part dry with air.

Step a – Measure the OFCCs to the required length (refer to the procedures in Cable Entry for measuring and stripping back the appropriate length of cable jacket). Then add sufficient slack to allow for at least two reterminations [40 mm (1.60 inches) of slack should be sufficient for one retermination].

Step b – Slip the heat shrink tubing (with the fiber identification), the connector boot and the crimp sleeve over the OFCC (see Figure 408–3–44).

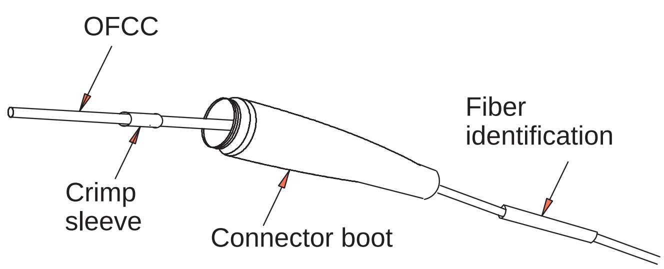

Figure 408–3–44. Installing the Identification Sleeve and Connector Boot – (typical)

Step c – Remove the OFCC jacket back 30 mm (1.20 in) from the end of the fiber using the OFCC stripper and trim the OFCC kevlar with the kevlar shears so that approximately 6 mm (0.25 in) extends past the OFCC jacket (see Figure 408–3–45).

WARNING

Wear safety glasses when removing the fiber buffer and coating to avoid possible eye injury.

Step d – Mark the fiber buffer 17 mm (0.70 in) back from the end of the fiber and remove the fiber buffer and coating back to the mark using the buffer stripper (see Figure 408–3–45). Remove the buffer and coating in small sections (approximately 6 mm (0.25 in) at a time.)

NOTE

Normally, the buffer and coating are tightly adhered to one another and come off of the fiber at the same time.

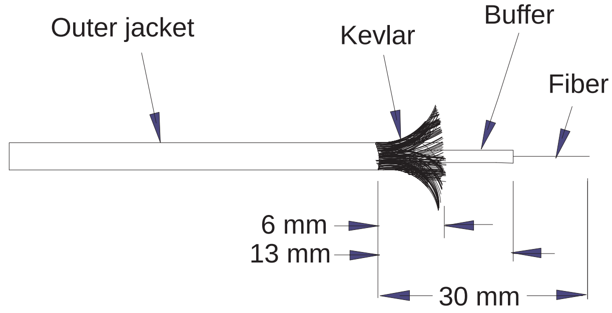

Figure 408−3−45. Prepared OFCC Dimensions

CAUTION

The uncoated fiber is in its most vulnerable state. Take extreme care not to damage the fiber.

Step e – Remove any residual coating material from the bare fiber with a wipe dampened with alcohol. Wipe once from the end of the buffer towards the end of the fiber.

NOTE

Do not repeatedly wipe the bare fiber as this will weaken the fiber.

408–3.8.7.3 Installation of Connectors onto Fibers

Step a – Inspect the connector and verify that the ferrule hole is free and clean of dirt. This can be accomplished by holding the front of the connector up to a light and verifying that the light is visible from the rear of the connector. If light cannot be seen through the connector, push music wire through the ferrule hole to clear it. Then blow dry air through the hole to remove any debris.

CAUTION

Do not introduce large air bubbles into the epoxy during the mixing process. Large air bubbles in the epoxy can lead to connector failure during temperature extremes.

Step b – Remove the divider from a 2–part epoxy package and mix the two parts together until the epoxy is a smooth uniform color (see Figure 408–3–46). The epoxy can be mixed by either repeatedly rolling the divider over the package or gently sliding the divider over the package.

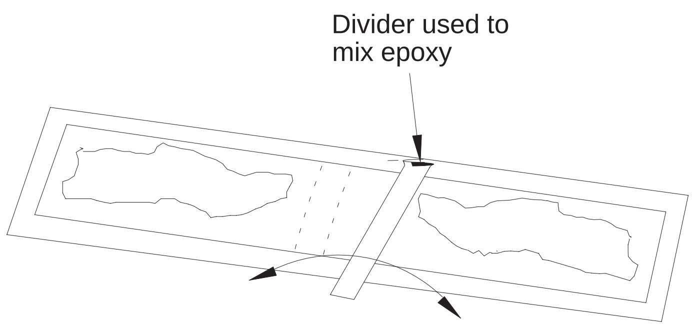

Figure 408−3−46. Mixing the Epoxy

NOTE

Verify that the epoxy shelf life has not expired. Do not use epoxy with an expiration date that has passed.

NOTE

Alternatively, the epoxy may be mixed by massaging the epoxy package by hand.

Step c – Install the syringe tip on the syringe, remove the plunger, and squeeze the epoxy into the syringe. Replace the plunger.

WARNING

Wear safety glasses while dispensing the epoxy to avoid possible eye injury.

Step d – Remove air pockets in the syringe by holding the tip of the syringe upward and dispensing epoxy onto a wipe until it runs free and clear.

Step e – Slide the connector, rear first, onto the syringe tip (see Figure 408–3–47). Depress the plunger and slowly inject epoxy into the connector until it escapes out of the ferrule, forming a very small bead.

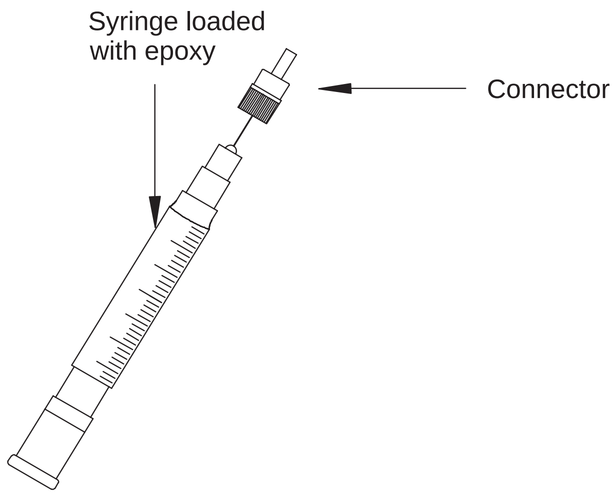

Figure 408–3–47. Injecting Epoxy into the Connector

NOTE

Do not overfill. Be extremely careful not to get epoxy on the connector spring or other connector moving parts.

Step f – Withdraw the syringe from the connector. Maintain some pressure on the plunger as the syringe is withdrawn so that the connector is completely filled with epoxy. Using a wipe dampened with alcohol, wipe away any epoxy on the outer diameter of the ferrule without disturbing the epoxy bead.

NOTE

Alternatively, the connector may be completely filled by maintaining a light pressure on the syringe plunger and allowing the epoxy to push the connector off of the syringe tip.

Step g – Apply a very thin coating of epoxy to the kevlar strands and the buffer.

Step h – Apply a very thin band of epoxy to approximately 3 mm (0.12 inch) of the connector barrel (see Figure 408–3–48).

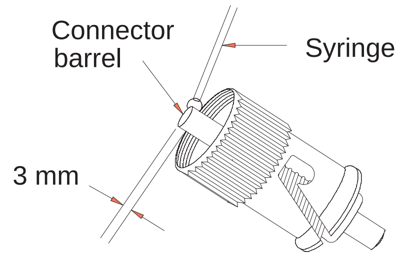

Figure 408–3–48. Applying Epoxy to the Connector Barrel

Step i – Feather the kevlar evenly around the fiber and insert the fiber into the rear of the connector (see Figure 408–3–49). Gently work the fiber through the connector until the buffer seats against the rear of the ferrule. The OFCC jacket should come up to the rear of the connector barrel and the kevlar should surround the rear of the connector barrel. Once inserted, do not allow the fiber to slip back.

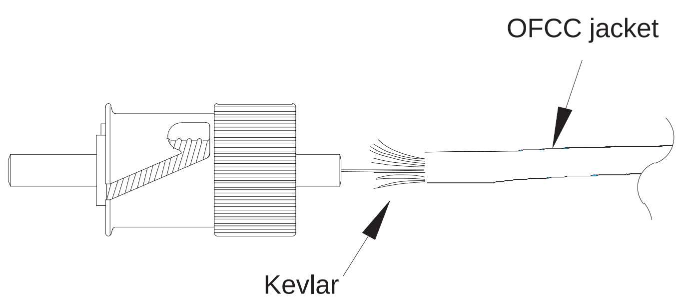

Figure 408–3–49. Inserting the Fiber into the Connector

Step j – Carefully place the cure adapter over the fiber and mate it to the connector so that the connector barrel is at maximum extension from the rear of the connector (place the cure adapter nub at end of the connector ramp, just before the normal mated position). Slide the crimp sleeve over the OFCC jacket and kevlar onto the connector barrel (see Figure 408–3–50).

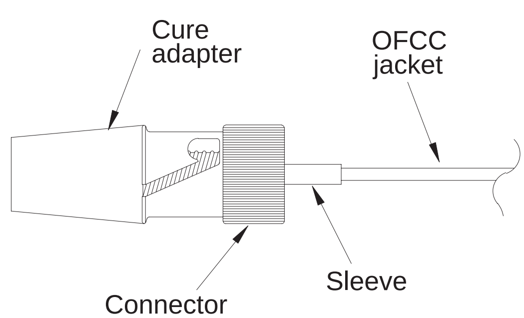

Figure 408–3–50. Sliding the Crimp Sleeve over the Connector Barrel

NOTE

The fiber must not protrude beyond the end of the cure adapter. If it does, trim the fiber end so it does not.

Step k – Place the crimping tool over the crimp sleeve and crimp it against the connector barrel. Rotate the connector 90 degrees and crimp it again (see Figure 408–3–51.

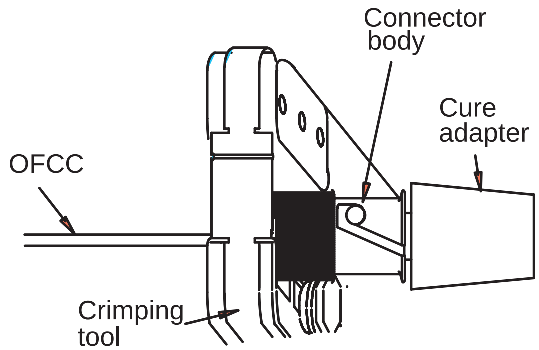

Figure 408–3–51. Crimping the Connector

Step l – Verify that there is a small amount of epoxy around the fiber where it protrudes from the ferrule. If it is found that there is no small bead of epoxy on the ferrule tip, carefully add a small amount of epoxy around the fiber.

NOTE

The cure adapter may be removed if the addition of epoxy is required. The cure adapter should be placed on the connector again after step m.

NOTE

There should only be a small amount of epoxy around the fiber to support it later during the polishing process. If too much epoxy is around the fiber during the curing process it may cause the fiber to crack.

Step m – Using a wipe dampened with alcohol, carefully wipe away any epoxy on the fiber that is more than 2 mm (0.08 in) from the ferrule surface.

Step n – Apply a drop of epoxy onto the rubber boot threads, slip the boot over the crimped sleeve and screw it onto the connector body.

408–3.8.7.4 Curing the Epoxy

Step a – Turn on the curing oven so that it attains the proper temperature before the connector is placed within it (approximately 20 minutes).

Step b – Place the cure adapter with the connector in the curing oven, and position the OFCC vertically over the oven. Cure the epoxy for a minimum of 10 minutes (maximum of 30 minutes) at 120°C (248°F).

NOTE

When the OFCC is positioned above the connector, make sure that no bends are placed in the OFCC. The OFCC should enter the connector parallel to the connector axis.

Step c – Turn the curing oven off, remove the connector and cure adapter from the curing oven, and place them on a cure adapter holder block or non–flammable surface. Allow the cure adapter and connector to cool for approximately 4 minutes.

408–3.8.7.5 Polishing the Fiber Ends. Hand polishing is the preferred method of polishing ferrules. Only procedures for hand polishing are contained herein.

NOTE

The procedures contained herein should produce an optical terminus with a physical contact (PC) polish.

WARNING

Wear safety glasses when scoring the fiber to avoid possible eye injury.

Step a – Remove the connector from the cure adapter and score the fiber close to the ferrule tip at the epoxy interface using one short light stroke with cleaving tool (see Figure 408–3–52). Pull off the fiber with a gentle, straight pull. Deposit the waste fiber in a trash container.

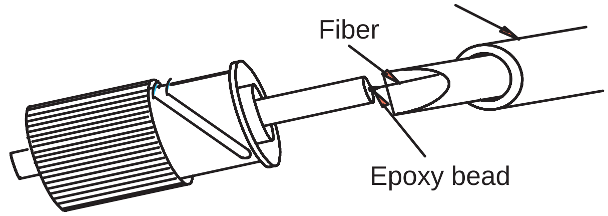

Figure 408–3–52. Scoring the Fiber

NOTE

Do not break the fiber with the cleaving tool.

Step b – Clean the glass polishing plate, the backs of the polishing papers, and the surface of the polishing tool using a wipe dampened with alcohol. Blow all of the surfaces dry with air.

NOTE

Before inserting the connector into the polishing tool, the connector may be held vertically and the end of the fiber polished off by lightly running the 5 μm polishing paper over the top of the ferrule tip. (This is referred to as air polishing the connector.)

Step c – Insert the connector into the polishing tool (see Figure 408–3–53).

NOTE

Difficulty in inserting the connector ferrule into the polishing tool may indicate epoxy on outside of the ferrule which must be removed before proceeding.

Step d – Place the 5 μm polishing paper on the glass plate and start polishing the connector with very light pressure (the weight of the tool) using a figure–8 motion (see Figure 408–3–54). Do not overpolish the connector. Since the polishing time varies with the amount of epoxy present on the tip of the ferrule, inspect the ferrule tip frequently. Whenever the polishing tool is lifted, remove the grit from the tool and the ferrule with air. When polishing is complete, clean the ferrule and the polishing tool using a wipe dampened with alcohol and blow them dry with air. Perform a rough inspection of the ferrule end using the eye loop.

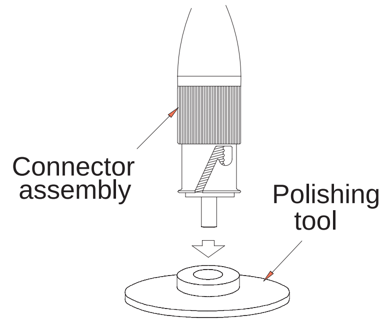

Figure 408–3–53. Inserting the Connecting into the Polishing Tool

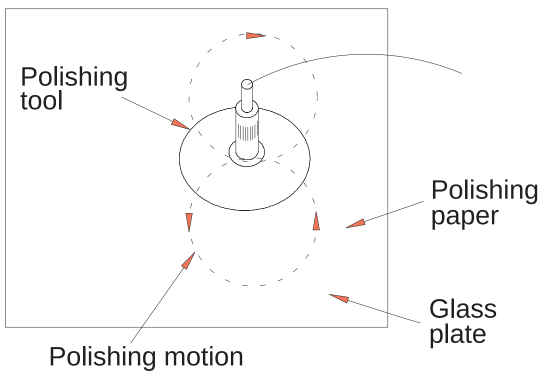

Figure 408–3–54. Polishing the Connector

NOTE

The first polish is complete when all of the epoxy is gone from the tip of the ferrule.

NOTE

For some ferrule designs all of the epoxy cannot be removed during the first polish and a slight epoxy haze will remain on the ferrule endface. This haze will be removed during the first 5 figure–8 motions of the second polish. If this occurs, polish the connector an additional 5 figure–8 motions during the second polish.

Step e – Replace the 5 μm paper with the 1 μm paper. Wet the paper and polish the connector with very light pressure using a figure–8 motion for 10 to 20 complete motions.

Step f – Remove the connector from the polishing tool, clean it using a wipe dampened with alcohol and blow it dry with air.

408–3.8.7.6 Quality Check

Step a – Examine the connector with the optical microscope to ensure that the optical surface is smooth and free of scratches, pits, chips, and fractures. If any defects are present, repeat steps 408–3.8.7.5 b, c, e, and f or reterminate the fiber (see Figure 408–3–55). A high intensity back light may be used to illuminate the fiber during the quality check.

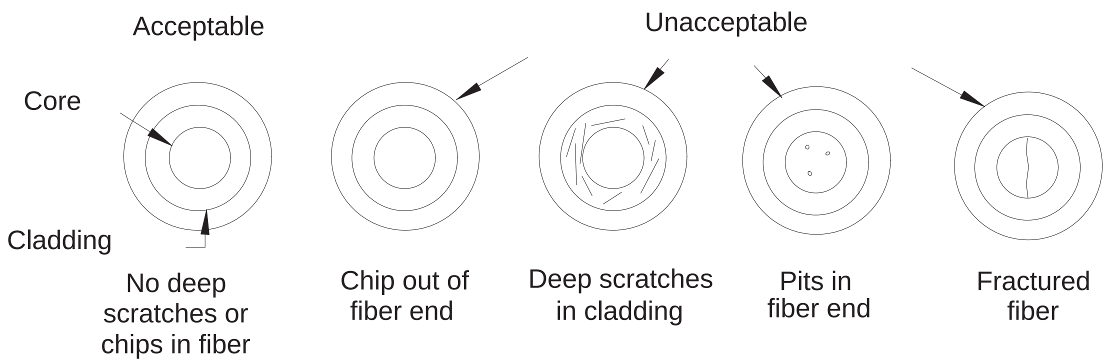

Figure 408−3−55. Quality Check

NOTE

Overpolishing the fiber will increase the optical loss of the connector. Do not polish the connector more than necessary to pass the quality check.

Step b – If the connector is not to be immediately mated into an adapter, install a plastic protective cap over the connector ferrule.

408–3.8.8 MULTIPLE FIBER CONNECTOR REPAIR. This section describes a procedure for installing MIL–C–28876 multiple terminus connectors on fiber optic cable. Method 1 covers connectors with removable backshells, Method 2 covers connectors with non-removable backshells, and Method 3 covers connectors with insert retention nuts. See Appendix C for additional information.

408–3.8.8.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers or dispensing epoxy.

2. Do not touch the ends of the fiber as they may be razor sharp. Wash your hands after handling bare fiber.

3. Avoid skin contact with epoxies.

4. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

408–3.8.8.2 METHOD 1: Installation of Connectors with Removable Backshells. This method shall be used to install connectors with part numbers M28876/1, M28876/6 and M28876/11 configured without insert retention nuts and backshells with part numbers M28876/27, M28876/28 and M28876/29 onto fiber optic cables. The equipment and materials Table 408–C–9 (Appendix C) shall be used to for this procedure.

408–3.8.8.2.1 Cable and Fiber Preparation

CAUTION

Throughout the termination process, cleanliness is critical to obtaining a high optical quality connector. Make sure that your hands and the work area are as clean as possible to minimize the ingress of dirt into the connector parts.

Step a – Ensure the cable is the correct type as specified on the applicable cable diagram.

Step b – Measure the cable to the required length. Then add sufficient slack to allow for at least two reterminations [191 mm (7.5 inches) of slack should be sufficient for one retermination].

Step c – Clean the outer cable jacket that will be in contact with the connector and backshell with a wipe dampened with alcohol and blow it dry with air.

NOTE

Keep the cable and connector parts free from oil, dirt and grease throughout the installation procedure. If cleaning is necessary, use a wipe dampened with alcohol and blow the part dry with air.

Step d – Slide the backshell parts onto the cable in the order indicated below (see Figure 408–3–56).

1. Backnut
2. “O”-ring
3. Spacer
4. Ferrule (kevlar grip)
5. Sheath (ensure “O”-rings are in place)
6. Backshell body

CAUTION

Do not cut or nick OFCC jackets.

Step e – Mark the cable jacket approximately 191 mm (7.5 inches) from the end and strip back the outer cable jacket to the mark using the cable stripper. Fold back the kevlar strength members and temporarily tape them to the cable outer jacket. Cut off the exposed central member and any fillers using the kevlar shears.

Step f – Remove any water blocking material, clean the OFCC’s using a wipe dampened with alcohol and blow them dry with air.

Step g – Trim the OFCC’s to dimension A Table 408–C–10 (Appendix C) using the kevlar shears (see Figure 408–3–57).

Step h – Feed each OFCC into a crimp sleeve and slide the sleeve back from the end of the OFCC.

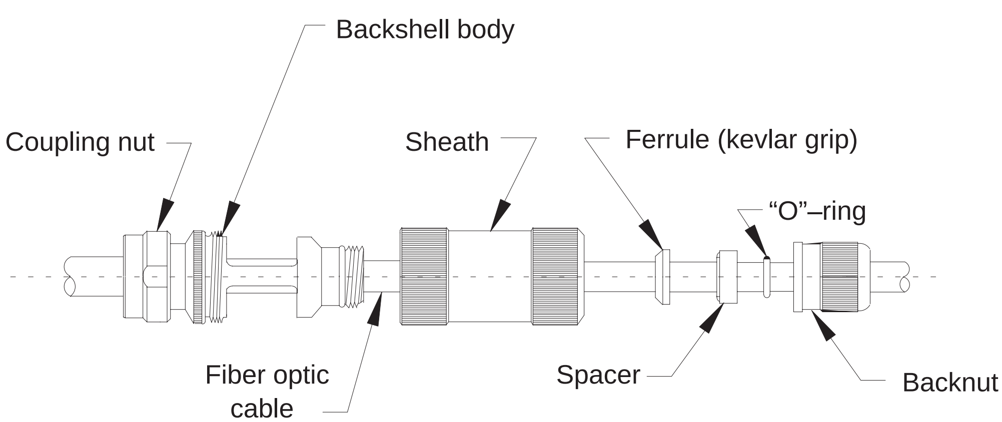

Figure 408–3–56. Backshell Parts on the Cable (Straight Backshell)

NOTE

Only use crimp sleeves intended for termini. Do not use crimp sleeves intended for other types of connectors. The standard crimp sleeve for the terminus may be oriented in either direction.

Step i – Remove the OFCC jackets back to dimension B Table 408–C–10 (Appendix C) using the OFCC stripper and trim the OFCC kevlar so that approximately 3 mm (0.12 in) extends past the OFCC jacket (see Figure 408–3–57).

WARNING

Wear safety glasses when removing the fiber buffer and coating to avoid possible eye injury.

Step j – Remove the fiber buffers and coatings back to dimension C Table 408–C–10 (Appendix C) using the buffer stripper (see Figure 408–3–57). Remove the buffer and coating in small sections (approximately 6 mm (0.25 in) at a time.)

NOTE

Normally, the buffer and coating are tightly adhered to one another and come off of the fiber at the same time.

CAUTION

The uncoated fiber is in its most vulnerable state. Take extreme care not to damage the fiber. Breakage of any one fiber from this point until the connector is completely assembled will require repetition of this and the following steps in order to maintain approximately equal length of all the fibers in the cable.

Step k – Remove any residual coating material from the bare fibers with a wipe dampened with alcohol. Wipe only once from the end of the buffer towards the end of the fiber.

NOTE

Do not repeatedly wipe the bare fiber as this will weaken the fiber.

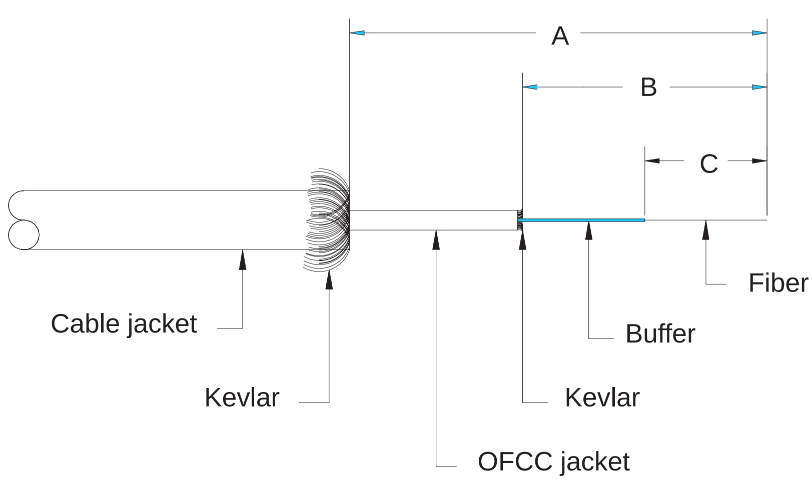

Figure 408–3–57. Cable Stripping Dimensions

408–3.8.8.2.2 Installation of Termini onto Fibers. This procedure describes the process for installing ceramic termini onto either multimode or single-mode fibers. The termini use epoxy to secure the fiber and a crimp sleeve to capture the kevlar strength members of the OFCC's.

Step a – Turn on the curing oven so that it attains the proper temperature before the termini are placed within it (approximately 20 minutes).

Step b – Inspect the terminus and verify that the ferrule hole is free and clean of dirt. This can be accomplished by holding the front of the terminus up to a light and verifying that the light is visible from the rear of the terminus. If light cannot be seen through the terminus, push music wire through the terminus hole to clear it. Then blow dry air through the hole to remove any debris.

Step c – Remove the divider from a 2–part epoxy package and mix the two parts together until the epoxy is a smooth uniform color (see Figure 408–3–58). The epoxy can be mixed by either repeatedly rolling the divider over the package or gently sliding the divider over the package.

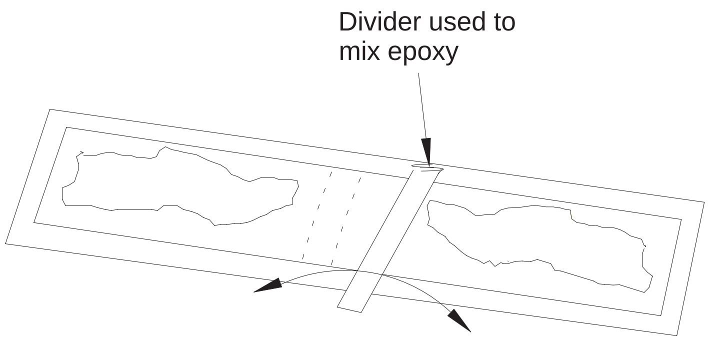

Figure 408–3–58. Mixing the Epoxy

NOTE

Verify that the epoxy shelf life has not expired. Do not use epoxy with an expiration date that has passed.

NOTE

Alternatively, the epoxy may be mixed by massaging the epoxy package by hand.

CAUTION

Do not introduce large air bubbles into the epoxy during the mixing process. Large air bubbles in the epoxy can lead to connector failure during temperature extremes.

Step d – Install the syringe tip on the syringe, remove the plunger, and squeeze the epoxy into the syringe. Replace the plunger.

WARNING

Wear safety glasses while dispensing the epoxy to avoid possible eye injury.

Step e – Remove air pockets in the syringe by holding the tip of the syringe upward and dispensing epoxy onto a wipe until it runs free and clear.

Step f – Slide the terminus, rear first, onto the syringe tip (see Figure 408–3–59). Keeping the syringe vertical, depress the plunger and slowly inject epoxy into the terminus until it escapes out of the ferrule, forming a very small bead.

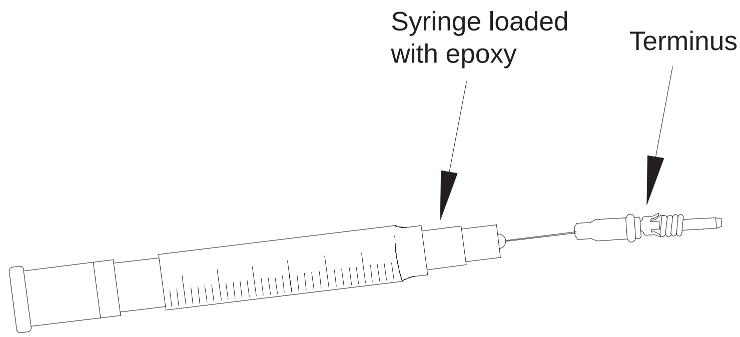

Figure 408–3–59. Injecting Epoxy into the Terminus

NOTE

Do not overfill. Be extremely careful not to get epoxy on the pin spring or other terminus moving parts.

Step g – Withdraw the syringe from the terminus. Maintain some pressure on the plunger as the syringe is withdrawn so that the terminus is completely filled with epoxy. Using a wipe dampened with alcohol, wipe away any epoxy on the outer diameter of ferrule without disturbing the epoxy bead.

NOTE

Alternatively, the terminus may be completely filled by maintaining a light pressure on the syringe plunger and allowing the epoxy to push the terminus off of the syringe tip.

Step h – Feather the kevlar evenly around the fiber and insert the fiber into the rear of the terminus (see Figure 408–3–60). Gently work the fiber through the terminus until the buffer seats against the rear of the ferrule. The OFCC jacket should come up to the rear of the terminus and the kevlar should surround the rear of the terminus. Once inserted, do not allow the fiber to slip back.

Step i – Slide the crimp sleeve over the kevlar and crimp it to the rear of the terminus using the crimp tool.

NOTE

A small amount of epoxy may be added on the kevlar near the rear of the terminus before the crimp sleeve is installed. However, no epoxy should be visible once the crimp sleeve is installed.

Step j – Verify that the kevlar does not protrude excessively from under the crimp sleeve. Excessive kevlar protrusion will cause the terminus to not seat properly in the finished connector. If excessive kevlar protrudes from under the crimp sleeve, trim it back using a razor blade.

Step k – Verify that there is a small amount of epoxy around the fiber where it protrudes from the ferrule. If it is found that there is no small bead of epoxy on the terminus tip, carefully add a small amount of epoxy around the fiber.

NOTE

There should only be a small amount of epoxy around the fiber to support it later during the polishing process. If too much epoxy is around the fiber during the curing process it may cause the fiber to crack.

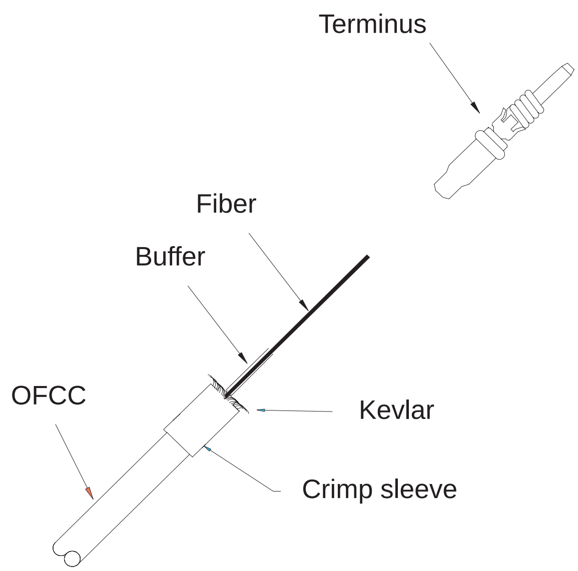

Figure 408−3−60. Inserting the Fiber into the Terminus

Step l – Using a wipe dampened with alcohol, carefully wipe away any excess epoxy on the fiber that is more than 2 mm (0.08 in) from the ferrule tip surface.

Step m – Insert the terminus into the cure adapter until it snaps into place (see Figure 408–3–61).

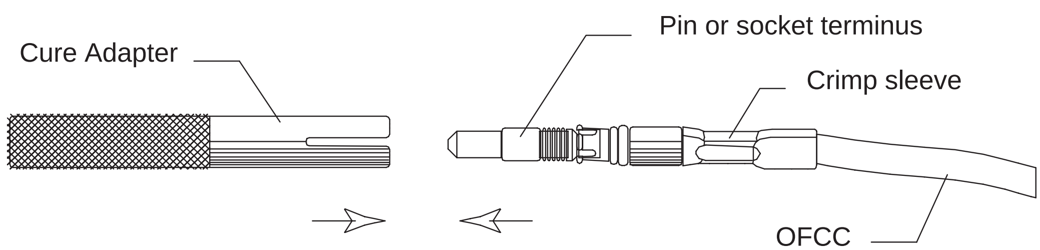

Figure 408−3−61. Inserting a Terminus into a Cure Adapter

Step n – Repeat steps b through m for each fiber to be terminated.

Step o – Place the cure adapters in the curing oven, and position the cable vertically over the oven using the cable stand, cable stand ring and cable clip (see Figure 408–3–62). Cure the epoxy for a minimum of 10 minutes (maximum of 30 minutes) at 120°C (248°F).

NOTE

> When the cable is positioned above the terminus, make sure that no bends are placed in the OFCCs. Each OFCC should enter the terminus parallel to the terminus.

Step p – Turn the curing oven off and remove the cure adapters and termini from the curing oven. Allow the cure adapters and termini to cool for approximately 4 minutes.

408–3.8.8.2.3 Polishing the Fiber Ends. Hand polishing is the preferred method of polishing termini. Only procedures for hand polishing are contained herein.

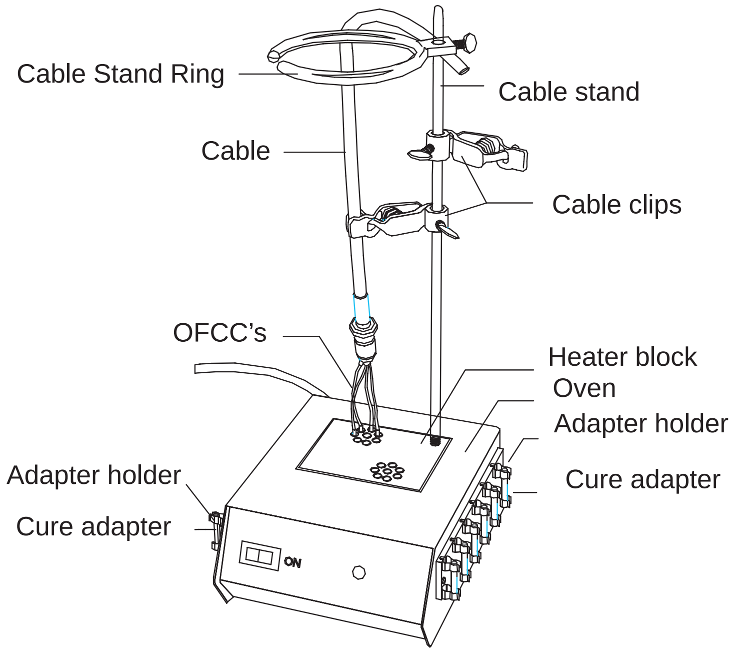

Figure 408–3–62. Termini in the Curing Oven

NOTE

The procedures contained herein should produce an optical terminus with a physical contact (PC) polish.

WARNING

Wear safety glasses when scoring the fiber to avoid possible eye injury.

Step a – Remove the terminus from the cure adapter and score the fiber close to the terminus tip at the epoxy interface using one short light stroke with cleaving tool (see Figure 408–3–63). Pull off each fiber with a gentle, straight pull. Deposit the waste fiber in a trash container.

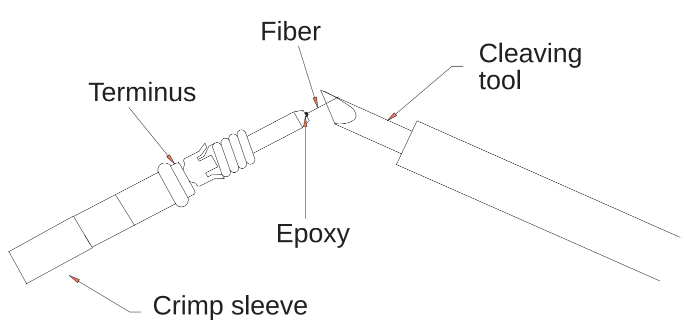

Figure 408–3–63. Scoring the Fiber

NOTE

Do not break the fibers with the cleaving tool.

NOTE

The termini not being polished should be left in the cure adapters during the polishing process to protect the fibers from breakage.

NOTE

Before inserting the terminus into the polishing tool, the terminus may be held vertically and the end of the fiber polished off by lightly running the 5 µm polishing paper over the top of the terminus tip. (This is referred to as air polishing the terminus.)

Step b – Rotate the top half of the polishing tool 90 degrees counterclockwise and separate the top from the base.

Step c – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–64).

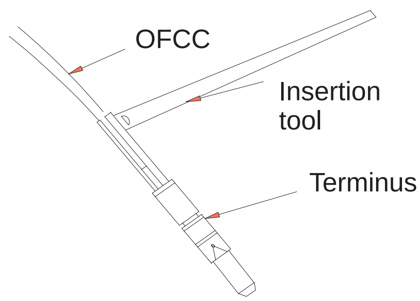

Figure 408–3–64. Placing the Terminus in the Insertion Tool

Step d – Insert the terminus into the center of the polishing tool top. Apply pressure with the insertion tool until the terminus snaps into place. Remove the tool by pulling straight back (see Figure 408–3–65).

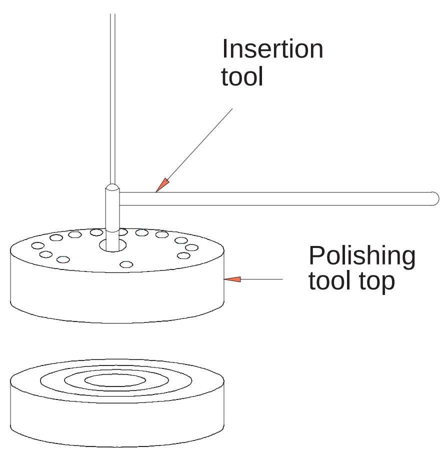

Figure 408–3–65. Inserting the Terminus in the Polishing Tool

NOTE

Difficulty in inserting the terminus into the polishing tool may indicate epoxy on outside of the terminus which must be removed before proceeding.

Step e – Install the top half of the polishing tool on the bottom half and rotate it clockwise (90 degrees) until it locks in place.

Step f – Clean the glass polishing plate, the backs of the polishing papers, and the surface of the polishing tool using a wipe dampened with alcohol. Blow all of the surfaces dry with air.

Step g – Place the 5 µm polishing paper on the glass plate and start polishing the terminus with very light pressure (the weight of the tool) using a figure–8 motion. Do not overpolish the terminus. Since the polishing time varies with the amount of epoxy present on the tip of the terminus, inspect the terminus tip frequently. Whenever the polishing tool is lifted, remove the grit from the tool and the terminus with air. When polishing is complete, clean the terminus and the polishing tool using a wipe dampened with alcohol and blow them dry with air. Perform a rough inspection of the ferrule end using the eye loop.

NOTE

The first polish is complete when all of the epoxy is gone from the tip of the terminus.

Step h – Replace the 5 µm paper with the 1 µm paper. Wet the paper and polish the terminus with very light pressure using a figure–8 motion for 10 to 20 complete motions.

Step i – Rotate the top of the polishing tool counterclockwise (90 degrees) and separate the top from the base. Insert the terminus removal tool into the bottom of the terminus cavity of the polishing tool top and press on the hilt of the removal tool until the tool clicks into place (see Figure 408–3–66). Depress the plunger and slide the terminus out of the polishing tool. Clean the terminus and the polishing tool with a wipe dampened with alcohol and blow them dry with air.

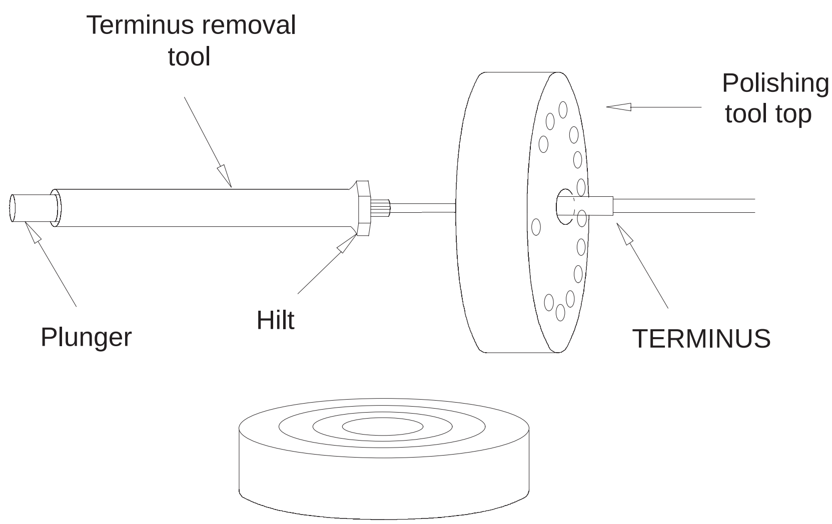

Figure 408–3–66. Removing the Terminus from the Polishing Tool

Step j – Repeat steps a through i for all of the termini.

408–3.8.8.2.4 Quality Check. Examine the terminus with the optical microscope to ensure that the optical surface is smooth and free of scratches, pits, chips, and fractures. If any defects are present, repeat steps b through f, h, and i or reterminate the fiber (see Figure 408–3–67).

NOTE

Overpolishing the fiber will increase the optical loss of the terminus. Do not polish the terminus more than necessary to pass the quality check.

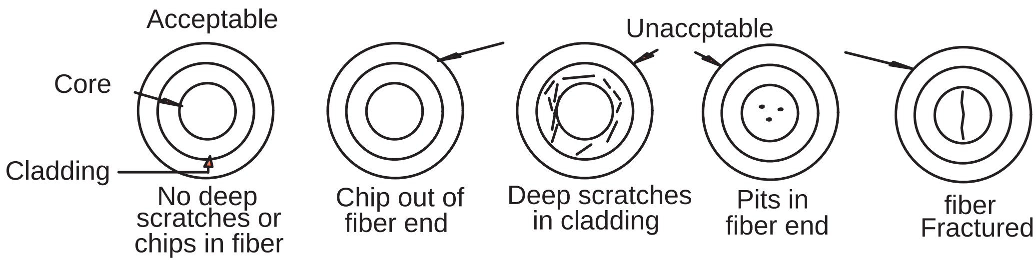

Figure 408–3–67. Quality Check

NOTE

A high intensity back light may be used to further illuminate fiber.

408–3.8.8.2.5 Installation of Terminus into Connector Insert

NOTE

The termini may be installed before or after the connector backshell has been assembled onto the connector shell. If the connector backshell has been assembled to the connector shell, the backshell sheath must be removed in order to install the termini.

Step a – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–68).

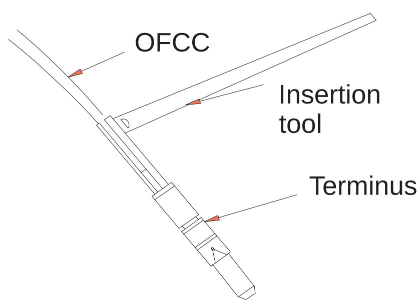

Figure 408–3–68. Placing the Terminus in the Insertion Tool

Step b – If it has not already been done, install the insert into the connector shell. Place the terminus in the proper cavity in the rear of the connector insert. Apply pressure with the insertion tool until the terminus snaps into place (see Figure 408–3–69). Remove the tool by pulling straight back.

NOTE

Make sure that the insert key is properly aligned in the connector shell keyway before installing the insert.

NOTE

A properly inserted terminus will have some axial “play” within the insert cavity.

NOTE

A socket terminus, unlike a pin terminus, will require installation of the alignment sleeves after seating the terminus.

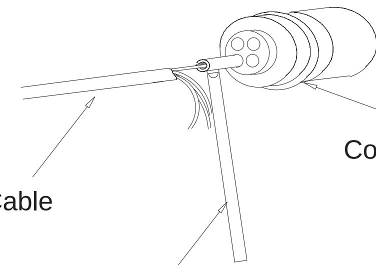

Figure 408−3−69. Installing the Terminus in the Insert

Step c – Proceed to step d below for socket termini. For pin termini repeat steps a and b for the rest of the termini.

CAUTION

Do not rotate the tool after the sleeve is installed in the insert.

Step d – Place the end of the socket terminus alignment sleeve installation and removal tool into the solid end of the alignment sleeve, depress the plunger to grasp the alignment sleeve, and press the sleeve into the socket terminus cavity in the face of the insert (see Figure 408–3–70). Press until the sleeve snaps onto the groove on the ceramic terminus body. Remove the tool by releasing the plunger and pulling straight back. Proceed to step e below.

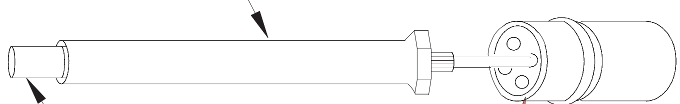

Figure 408−3−70. Installing the Alignment Sleeve

Step e – Repeat steps a through d for all of the termini.

408–3.8.8.2.6 Removal of Termini from the Connector Insert

NOTE

Perform this procedure only if the termini are to be removed from the connector.

NOTE

Proceed to step a below for socket termini. Proceed to step b below for pin termini.

CAUTION

Do not rotate the tool while the sleeve is in the insert.

Step a – Remove the alignment sleeves from the socket termini using the terminus alignment sleeve installation and removal tool by inserting the tool end into the alignment sleeve and depressing the plunger so that the tool grasps the sleeve lip. Pull the sleeve straight back. Proceed to step b.

Step b – Insert the terminus removal tool into the terminus cavity from the front of the insert and press on the hilt of the tool until it snaps into place (see Figure 408–3–71). Depress the plunger to slide the terminus out the rear of the insert.

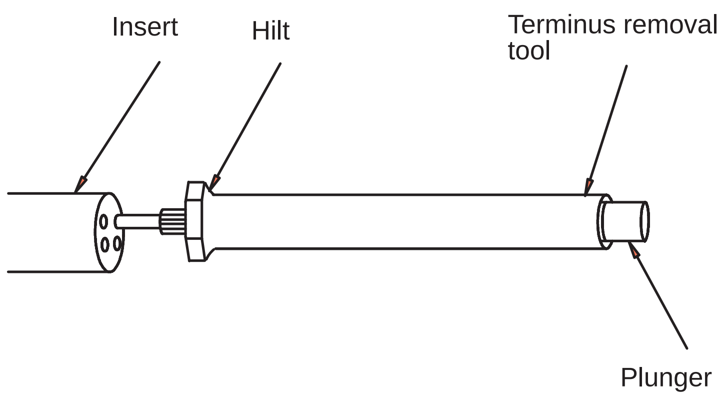

Figure 408–3–71. Removing the Terminus from the Insert

408–3.8.8.2.7 Assembly of the Backshell

NOTE

If the termini have been installed in the connector insert previously, take care to not pinch or twist the OFCCs during this procedure.

Step a – Slide the backshell body forward and screw it onto the connector shell until tight.

NOTE

Loctite or a similar material may be used to secure the backshell body to the connector shell. If Loctite or a similar material is used, use it sparingly.

Step b – Remove the tape securing the kevlar strength members and slide the ferrule (kevlar grip) up to rear of backshell capturing the kevlar between the backshell and kevlar grip. Comb the kevlar over kevlar grip and retape the kevlar to the cable.

Step c – Slide the spacer over the kevlar up to the rear of the kevlar grip.

Step d – Remove the tape and trim the kevlar approximately 6 mm (0.25 in) behind the spacer using the kevlar shears.

Step e – Apply O-ring lube to the O-ring and slide the O-ring up behind the spacer, keeping the kevlar strands between the O-ring and the spacer.

Step f – Slide the backnut forward over the O-ring, spacer, and kevlar grip and screw it tightly to the backshell body.

NOTE

Use an adjustable wrench on the backshell body flats and the backshell grip on the backnut. Use care to not nick or scratch the backshell coating during assembly.

Step g – Apply O-ring lube to the O-rings on the sheath and slide the sheath forward and screw it onto the backshell body until it is tight.

Step h – Install the plastic protective cap over the front of the connector.

408–3.8.9 METHOD 2: INSTALLATION OF CONNECTORS WITH NON REMOVABLE BACKSHELLS. This method shall be used to install connectors with part numbers M28876/2, M28876/3, M28876/4, M28876/7, M28876/8, M28876/9, M28876/12, M28876/13, and M28876/14 onto fiber optic cables. The equipment and materials in Table 408–C–11 (Appendix C) shall be used to perform this procedure.

CAUTION

Throughout the termination process, cleanliness is critical to obtaining a high optical quality connector. Make sure that your hands and the work area are as clean as possible to minimize the ingress of dirt into the connector parts.

408–3.8.9.1 Cable Preparation

NOTE

The connector is received assembled with O-rings installed, with the exception of the kevlar retaining O-ring which is taped to the backshell exterior.

Step a – Ensure cable is the correct type as specified on the applicable cable diagram.

Step b – Measure the cable to the required length. Then add sufficient slack to allow for at least two reterminations [178 mm (7 inches) of slack should be sufficient for one retermination].

Step c – Clean the outer cable jacket that will be in contact with the connector and backshell with a wipe dampened with alcohol and blow it dry with air.

NOTE

Keep the cable and connector parts free from oil, dirt, and grease throughout the installation procedure. If cleaning is necessary, use a wipe dampened with alcohol and blow the parts dry with air.

408–3.8.9.1.1 Securing the Strain Relief

Step a – Slide the strain relief onto cable in the order indicated (see Figure 408–3–72):

1. Compression nut with boot
2. Shrink tubing
3. Strain relief housing
4. Compression ring

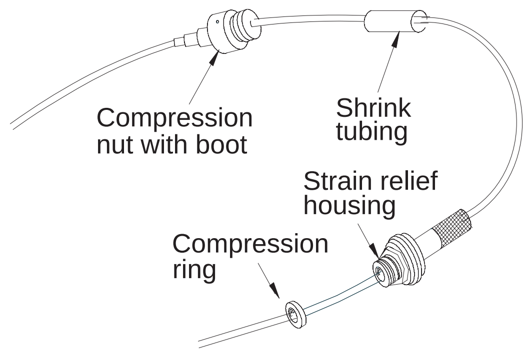

Figure 408–3–72. Strain Relief Parts to the Cable

Step b – Mark the cable approximately 165 mm (6.5 in) from the end and strip back the outer cable jacket using the cable stripper. Fold back the kevlar strength members and temporarily tape them to the cable outer jacket.

CAUTION

Do not cut or nick the OFCC jackets.

Step c – Cut off the exposed central member and any fillers using the kevlar shears.

Step d – Remove any water blocking material and clean the OFCC’s using a wipe dampened with alcohol and blow them dry with air.

Step e – Remove the tape from the kevlar strength members and fold them forward. Slide the compression ring to the end of the cable jacket. Fold the kevlar strength members back over the compression ring and the cable in the direction of the strain relief housing.

NOTE

The grooved side of ring should face the strain relief housing.

Step f – Remove the O-ring (taped to the backshell exterior) and apply O-ring lubricant. Place the O-ring on the O-ring installation tool by forcing the O-ring up the cone to the larger end of the tool.

Step g – Slide the O-ring tool up the OFCCs (larger opening first) over the compression ring (and kevlar strength members) and force the O-ring over the compression ring onto the kevlar (see Figure 408–3–73). Remove the O-ring tool.

Step h – Fold the kevlar strength members forward over the O-ring and the compression ring. Tape the kevlar members to the OFCCs to ease the installation of the kevlar compression nut.

Step i – Slide the strain relief housing up the cable to the compression ring. Gently feed the OFCCs and kevlar through the kevlar compression nut and slide the nut up to the strain relief housing. Thread the compression nut onto the strain relief housing while pulling the kevlar taut.

Step j – Tighten the kevlar compression nut to 2.75 N•m (25 inch–pounds) using the wrench, the torque adapter, the hex adapter, and the torque tool (see Figure 408–3–74). Remove the wrench and the other tools.

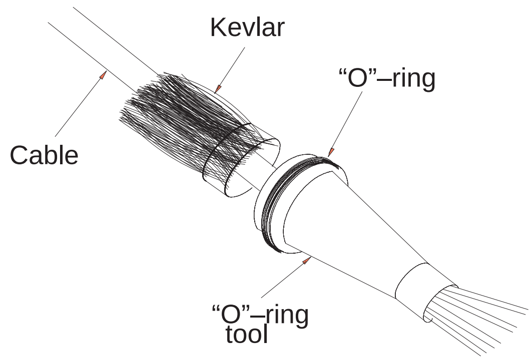

Figure 408–3–73. Installing the O-Ring

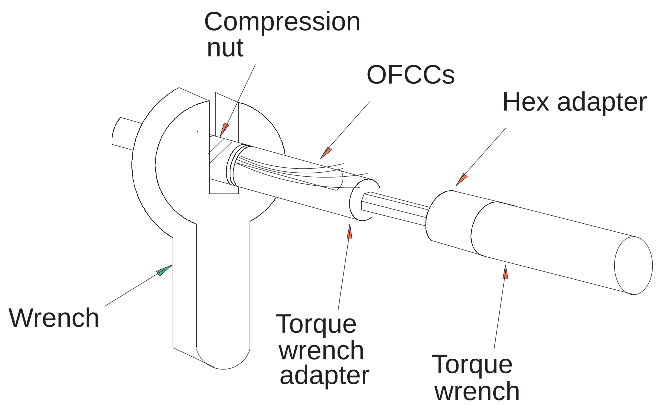

Figure 408–3–74. Tightening the Kevlar Compression Nut

Step k – Remove the tape and trim the kevlar down to the face of the kevlar compression nut using the kevlar shears.

NOTE

The following step may be performed at this time or later in the connector assembly process after completion of the quality check.

CAUTION

Do not overheat the cable. Prolonged exposure of the jacket to temperatures above 160°C (320°F) may damage the cable jacket. Discontinue heating of the tubing and allow the cable jacket to cool before reheating if the cable jacket shows any signs of bubbling or necking.

Step l – Slide the shrink tubing over the knurled end of the strain relief housing up to the shoulder. Starting at the strain relief housing, hold the heat gun approximately 102 mm (4 inches) from the tubing and apply heat until the tubing shrinks to a tight fit.

408–3.8.9.1.2 Fiber Preparation

Step a – Feed each OFCC into a crimp sleeve and slide the sleeve back from the end of the OFCC.

NOTE

Only use crimp sleeves intended for termini. Do not use crimp sleeves intended for other types of connectors. The standard crimp sleeve for the terminus may be oriented in either direction.

Step b – Trim the OFCC's to dimension A Table 408–C–12 (Appendix C) using the kevlar shears (see Figure 408–3–75).

Step c – Remove the OFCC jackets back to dimension B Table 408–C–12 (Appendix C) using the OFCC stripper and trim the OFCC kevlar so that approximately 3 mm (0.12 in) extends past the OFCC jacket (see Figure 408–3–75).

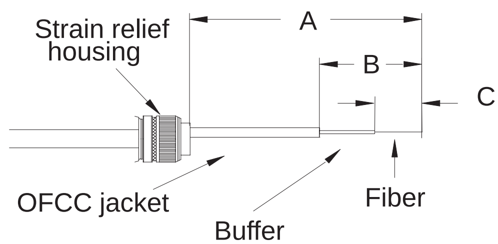

Figure 408–3–75. Cable Stripping Dimensions

WARNING

Wear safety glasses when removing the fiber buffer and coating to avoid possible eye injury.

Step d – Remove the fiber buffers and coatings back to dimension C Table 408–C–12 (Appendix C) using the buffer stripper (see Figure 408–3–75). Remove the buffer and coating in small sections (approximately 6 mm (0.25 in) at a time).

NOTE

Normally, the buffer and coating are tightly adhered to one another and come off of the fiber at the same time.

CAUTION

The uncoated fiber is in its most vulnerable state. Take extreme care not to damage the fiber. Breakage of any one fiber from this point until the connector is completely assembled will require repetition of this and the following steps in order to maintain approximately equal length of all the fibers in the cable.

Step e – Remove any residual coating material from the bare fibers with a wipe dampened with alcohol. Wipe only once from the end of the buffer towards the end of the fiber.

NOTE

Do not repeatedly wipe the bare fiber as this will weaken the fiber.

408–3.8.9.1.3 Installation of Termini onto Fibers. This procedure describes the process for installing ceramic termini onto either multimode or single-mode fibers. The termini use epoxy to secure the fiber and a crimp sleeve to capture the kevlar strength members of the OFCC's.

Step a – Turn on the curing oven so that it attains the proper temperature before the termini are placed within it (approximately 20 minutes).

Step b – Inspect the terminus and verify that the ferrule hole is free and clean of dirt. This can be accomplished by holding the front of the terminus up to a light and verifying that the light is visible from the rear of the terminus. If light cannot be seen through the terminus, push music wire through the terminus hole to clear it. Then blow dry air through the hole to remove any debris.

Step c – Remove the divider from a 2–part epoxy package and mix the two parts together until the epoxy is a smooth uniform color (see Figure 408–3–76). The epoxy can be mixed by either repeatedly rolling the divider over the package or gently sliding the divider over the package.

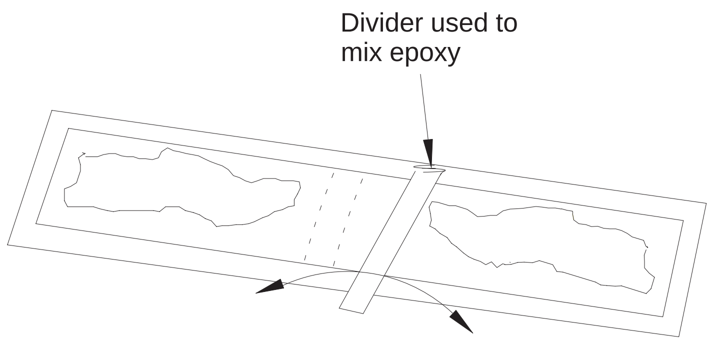

Figure 408–3–76. Mixing the Epoxy

NOTE

Verify that the epoxy shelf life has not expired. Do not use epoxy with an expiration date that has passed.

NOTE

Alternatively, the epoxy may be mixed by massaging the epoxy package by hand.

CAUTION

Do not introduce large air bubbles into the epoxy during the mixing process. Large air bubbles in the epoxy can lead to connector failure during temperature extremes.

Step d – Install the syringe tip on the syringe, remove the plunger, and squeeze the epoxy into the syringe. Replace the plunger.

WARNING

Wear safety glasses while dispensing the epoxy to avoid possible eye injury.

Step e – Remove air pockets in the syringe by holding the tip of the syringe upward and dispensing epoxy onto a wipe until it runs free and clear.

Step f – Slide the terminus, rear first, onto the syringe tip (see Figure 408–3–77). Keeping the syringe vertical, depress the plunger and slowly inject epoxy into the terminus until it escapes out of the ferrule, forming a very small bead.

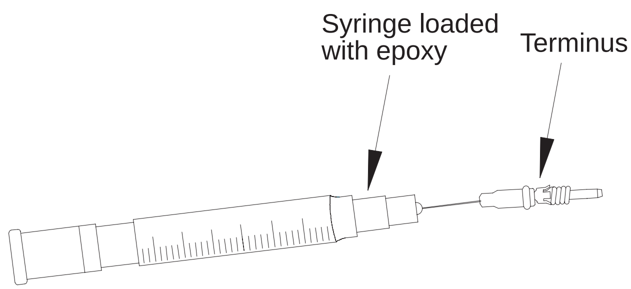

Figure 408−3−77. Injecting Epoxy into the Terminus

NOTE

Do not overfill. Be extremely careful not to get epoxy on the pin spring or other terminus moving parts.

Step g – Withdraw the syringe from the terminus. Maintain some pressure on the plunger as the syringe is withdrawn so that the terminus is completely filled with epoxy. Using a wipe dampened with alcohol, wipe away any epoxy on the outer diameter of ferrule without disturbing the epoxy bead.

NOTE

Alternatively, the terminus may be completely filled by maintaining a light pressure on the syringe plunger and allowing the epoxy to push the terminus off of the syringe tip.

Step h – Feather the kevlar evenly around the fiber and insert the fiber into the rear of the terminus (see Figure 408–3–78). Gently work the fiber through the terminus until the buffer seats against the rear of the ferrule. The OFCC jacket should come up to the rear of the terminus and the kevlar should surround the rear of the terminus. Once inserted, do not allow the fiber to slip back.

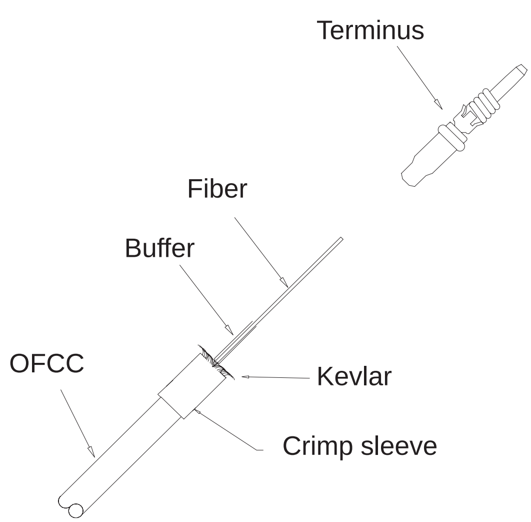

Figure 408−3−78. Inserting the Fiber into the Terminus

Step i – Slide the crimp sleeve over the kevlar and crimp it to the rear of the terminus using the crimp tool.

NOTE

A small amount of epoxy may be added on the kevlar near the rear of the terminus before the crimp sleeve is installed. However, no epoxy should be visible once the crimp sleeve is installed.

Step j – Verify that the kevlar does not protrude excessively from under the crimp sleeve. Excessive kevlar protrusion will cause the terminus to not seat properly in the finished connector. If excessive kevlar protrudes from under the crimp sleeve, trim it back using a razor blade.

Step k – Verify that there is a small amount of epoxy around the fiber where it protrudes from the ferrule. If it is found that there is no small bead of epoxy on the terminus tip, carefully add a small amount of epoxy around the fiber.

NOTE

There should only be a small amount of epoxy around the fiber to support it later during the polishing process. If too much epoxy is around the fiber during the curing process it may cause the fiber to crack.

Step l – Using a wipe dampened with alcohol, carefully wipe away any excess epoxy on the fiber that is more than 2 mm (0.08 in) from the ferrule tip surface.

Step m – Insert the terminus into the cure adapter until it snaps into place (see Figure 408–3–79).

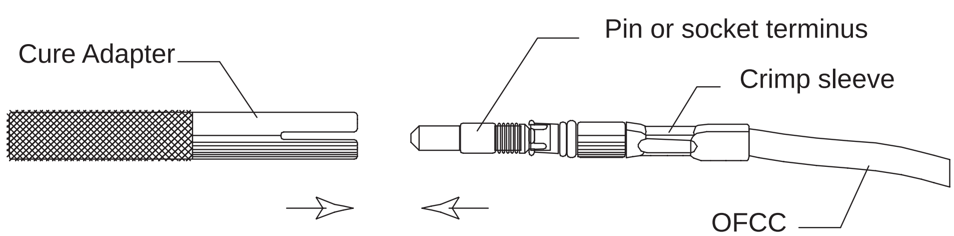

Figure 408–3–79. Inserting a Terminus in a Cure Adapter

Step n – Repeat steps b through m for each fiber to be terminated.

Step o – Place the cure adapters in the curing oven, and position the cable vertically over the oven using the cable stand, cable stand ring and cable clip (see Figure 408–3–80). Cure the epoxy for a minimum of 10 minutes (maximum of 30 minutes) at 120°C (248°F).

NOTE

When the cable is positioned above the terminus, make sure that no bends are placed in the OFCCs. Each OFCC should enter the terminus parallel to the terminus.

Step p – Turn the curing oven off and remove the cure adapters and termini from the curing oven. Allow the cure adapters and termini to cool for approximately 4 minutes.

408–3.8.9.1.4 Polishing the Fiber Ends. Hand polishing is the preferred method of polishing termini. Only procedures for hand polishing are contained herein.

NOTE

The procedures contained herein should produce an optical terminus with a physical contact (PC) polish.

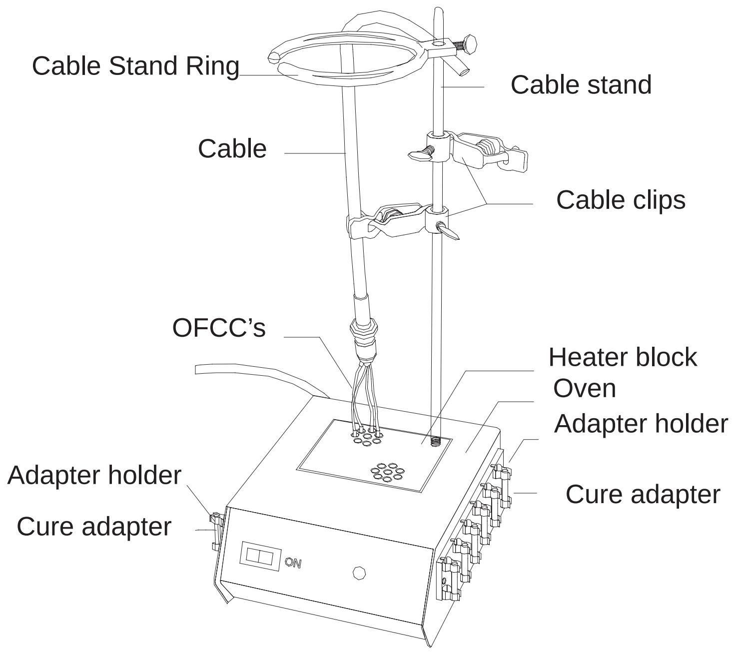

Figure 408–3–80. Termini in the Curing Oven

WARNING

Wear safety glasses when scoring the fiber to avoid possible eye injury.

Step a – Remove the terminus from the cure adapter and score the fiber close to the terminus tip at the epoxy interface using one short light stroke with cleaving tool (see Figure 408–3–81). Pull off each fiber with a gentle, straight pull. Deposit the waste fiber in a trash container.

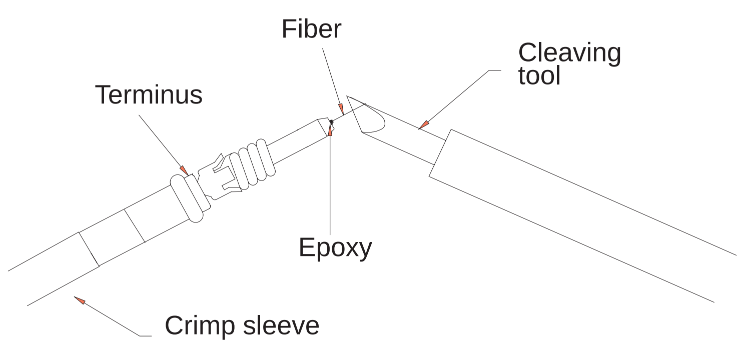

Figure 408–3–81. Scoring the Fiber

NOTE

Do not break the fibers with the cleaving tool.

NOTE

The termini not being polished should be left in the cure adapters during the polishing process to protect the fibers from breakage.

NOTE

Before inserting the terminus into the polishing tool, the terminus may be held vertically and the end of the fiber polished off by lightly running the 5 μm polishing paper over the top of the terminus tip. (This is referred to as air polishing the terminus.)

Step b – Rotate the top half of the polishing tool 90 degrees counterclockwise and separate the top from the base.

Step c – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–82).

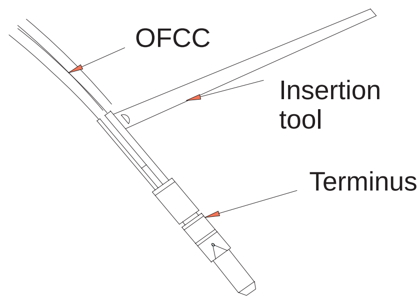

Figure 408–3–82. Placing the Terminus in the Insertion Tool

Step d – Insert the terminus into the center of the polishing tool top. Apply pressure with the insertion tool until the terminus snaps into place. Remove the tool by pulling straight back (see Figure 408–3–83).

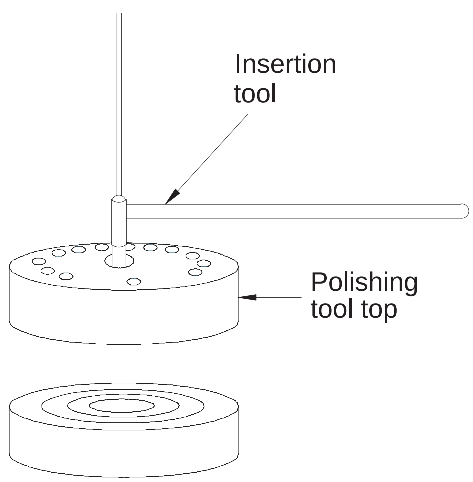

Figure 408–3–83. Inserting the Terminus into the Polishing Tool

NOTE

Difficulty in inserting the terminus into the polishing tool may indicate epoxy on outside of the terminus which must be removed before proceeding.

Step e – Install the top half of the polishing tool on the bottom half and rotate it clockwise (90 degrees) until it locks in place.

Step f – Clean the glass polishing plate, the backs of the polishing papers, and the surface of the polishing tool using a wipe dampened with alcohol. Blow all of the surfaces dry with air.

Step g – Place the 5 μm polishing paper on the glass plate and start polishing the terminus with very light pressure (the weight of the tool) using a figure–8 motion. Do not overpolish the terminus. Since the polishing time varies with the amount of epoxy present on the tip of the terminus, inspect the terminus tip frequently. Whenever the polishing tool is lifted, remove the grit from the tool and the terminus with air. When polishing is complete, clean the terminus and the polishing tool using a wipe dampened with alcohol and blow them dry with air. Perform a rough inspection of the ferrule end using the eye loop.

NOTE

The first polish is complete when all of the epoxy is gone from the tip of the terminus.

Step h – Replace the 5 μm paper with the 1 μm paper. Wet the paper and polish the terminus with very light pressure using a figure–8 motion for 10 to 20 complete motions.

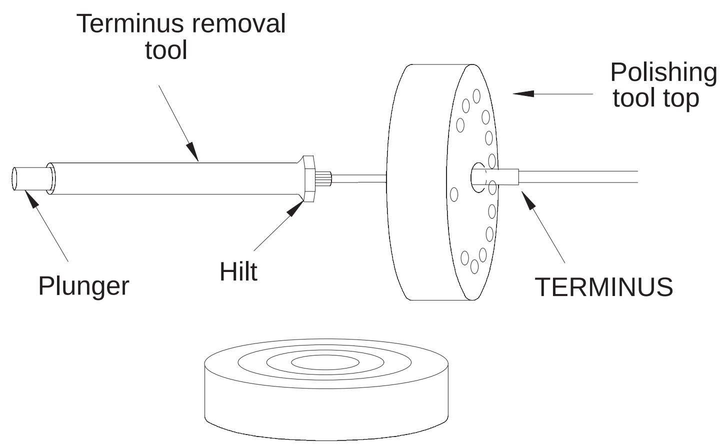

Figure 408–3–84. Removing the Terminus from the Polishing Tool

Step i – Rotate the top of the polishing tool counterclockwise (90 degrees) and separate the top from the base. Insert the terminus removal tool into the bottom of the terminus cavity of the polishing tool top and press on the hilt of the removal tool until the tool clicks into place (see Figure 408–3–84). Depress the plunger and slide the terminus out of the polishing tool. Clean the terminus and the polishing tool with a wipe dampened with alcohol and blow them dry with air.

Step j – Repeat steps a through i for all of the termini.

408–3.8.9.1.5 Quality Check. Examine the terminus with the optical microscope to ensure that the optical surface is smooth and free of scratches, pits, chips, and fractures. If any defects are present, repeat steps 408–3.8.9.1.4 b through f, h, and i or reterminate the fiber (see Figure 408–3–85).

NOTE

Overpolishing the fiber will increase the optical loss of the terminus. Do not polish the terminus more than necessary to pass the quality check.

NOTE

A high intensity back light may be used to further illuminate fiber.

408–3.8.9.1.6 Installation of Terminus into Connector Insert

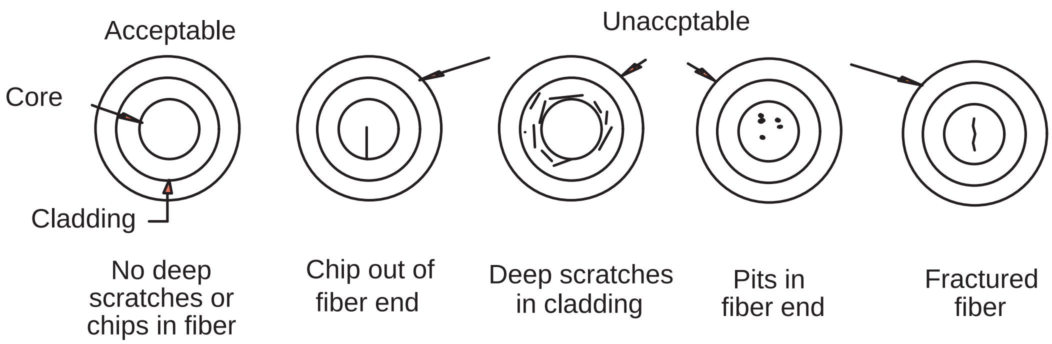

Figure 408–3–85. Quality Check

NOTE

Proceed to step a for straight (in-line) backshell connectors. Proceed to step b for 45° or 90° (angle) backshell connectors.

Step a – Fit the spacing shafts of the insert into the notches in the face of the strain relief until they snap into place (see Figure 408–3–86). Proceed to step c.

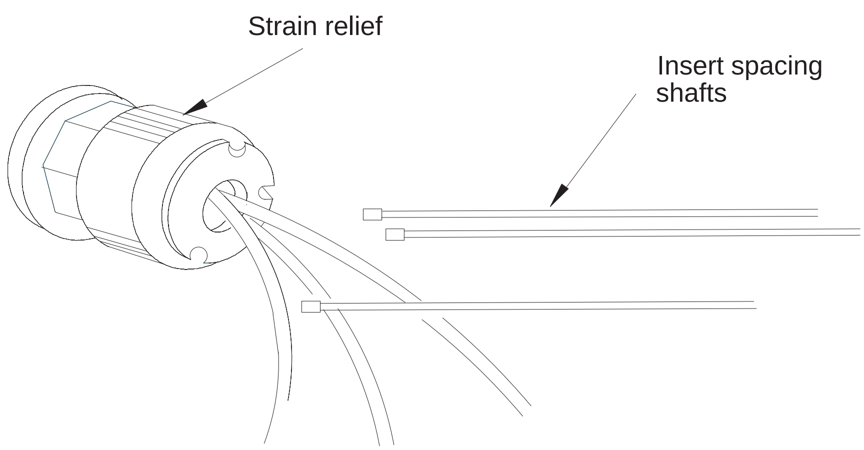

Figure 408–3–86. Installing the Spacing Shafts

Step b – Slide the strain relief/cable assembly into the backshell. When the strain relief assembly stops, rotate the backshell until the strain relief assembly aligns with the backshell. When they are aligned, fully seat the strain relief assembly by sliding it the rest of the way into the backshell. Proceed to step c.

NOTE

A properly seated strain relief assembly should be recessed approximately 10 mm (.4 in) from the rear of the backshell.

Step c – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–87).

Step d – Place the terminus in the proper cavity in the rear of the connector insert. Apply pressure with the insertion tool until the terminus snaps into place (see Figure 408–3–88). Remove the tool by pulling straight back.

NOTE

A properly inserted terminus will have some axial “play” within the insert cavity.

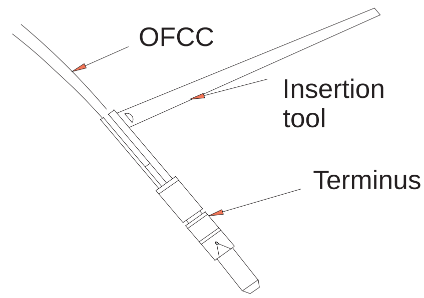

Figure 408–3–87. Placing the Terminus in the Insertion Tool

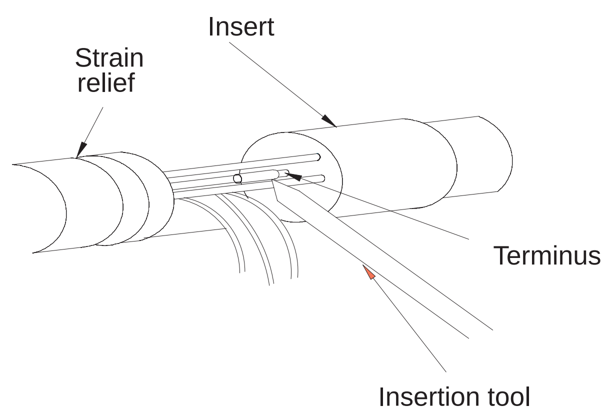

Figure 408–3–88. Installing the Terminus into the Insert

NOTE

A socket terminus, unlike a pin terminus, will require installation of the alignment sleeves after seating the terminus.

Step e – Proceed to step f below for socket termini. For pin termini repeat steps c and d for the rest of the termini.

Step f – Place the end of the socket terminus alignment sleeve installation and removal tool into the solid end of the alignment sleeve, depress the plunger to grasp the alignment sleeve, and press the sleeve into the socket terminus cavity in the face of the insert (see Figure 408–3–89). Press until the sleeve snaps onto the groove on the ceramic terminus body. Remove the tool by releasing the plunger and pulling straight back. Proceed to step g below.

Step g – Repeat steps a through f for all of the termini.

CAUTION

Do not rotate the tool after the sleeve is installed in the insert.

408–3.8.9.1.7 Removal of Termini from the Connector Insert

NOTE

Perform this procedure only if the termini are to be removed from the connector.

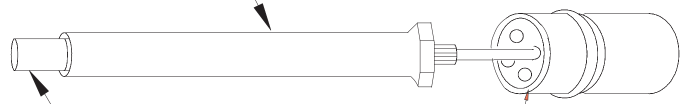

Figure 408–3–89. Installing the Alignment Sleeve

NOTE

Proceed to step a below for socket termini. Proceed to step b below for pin termini.

CAUTION

Do not rotate the tool while the sleeve is in the insert.

Step a – Remove the alignment sleeves from the socket termini using the terminus alignment sleeve installation and removal tool by inserting the tool end into the alignment sleeve and depressing the plunger so that the tool grasps the sleeve lip. Pull the sleeve straight back. Proceed to step b.

Step b – Insert the terminus removal tool into the terminus cavity from the front of the insert and press on the hilt of the tool until it snaps into place (see Figure 408–3–90). Depress the plunger to slide the terminus out the rear of the insert.

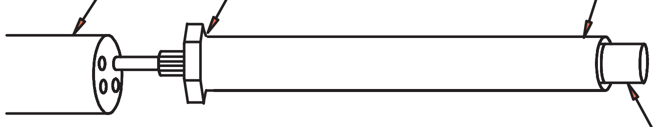

Figure 408–3–90. Removing the Terminus from the Insert

408–3.8.9.2 Assembly of the Backshell

408–3.8.9.2.1 Straight Backshells

Step a – Slide the insert/strain relief/cable assembly into the backshell (see Figure 408–3–91). When the insert stops, rotate the backshell until the key on the insert aligns with the keyway in the backshell. When they are aligned, fully seat the insert by sliding the insert/strain relief/cable assembly the rest of the way into the backshell.

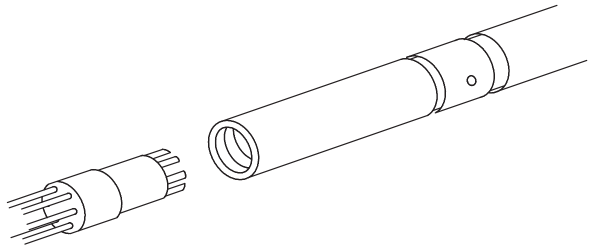

Figure 408−3−91. Assembling the Backshell

NOTE

A properly seated insert should cause the strain relief assembly to be recessed approximately 10 mm (.4 in) from the rear of the backshell.

CAUTION

Make sure that the insert key is properly aligned in the connector shell keyway and the insert fully seated in the connector shell before threading the compression nut into the backshell. Failure to properly seat the insert in the connector shell will cause breakage of the spacer shafts when the compression nut is threaded into the connector shell.

Step b – Slide the compression nut up to the backshell, thread it into the backshell and tighten it using the spanner wrench, torque wrench and backshell grip to 6.6 Nm (60 inch-pounds). Use care to not nick or scratch the backshell coating during assembly.

Step c – Install the plastic protective cap over the front of the connector.

408–3.8.10 45° AND 90° BACKSHELLS

CAUTION

Make sure that the OFCC's will not be pinched between the two backshell halves before assembling the backshell halves.

Step a – Assemble the two backshell halves together using a screwdriver.

Step b – Slide the compression nut up to the backshell, thread it into the backshell and tighten it using the spanner wrench, torque wrench and backshell grip to 6.6 Nm (60 inch-pounds). Use care to not nick or scratch the backshell coating during assembly.

Step c – Install the plastic protective cap over the front of the connector.

408–3.8.10.1 METHOD 3: Installation of Connectors with Insert Retention Nuts. This method shall be used to assemble connectors with part numbers M28876/1 and M28876/11 configured with insert retention nuts onto OFCCs. The equipment and materials Table 408–C–11 (Appendix C) shall be used to perform this procedure.

NOTE

This procedure is applicable in the installation of connector receptacles into equipment where the termination is accomplished on OFCCs. This procedure is not appropriate for the installation of plugs or receptacles onto multifiber cables.

CAUTION

Throughout the termination process, cleanliness is critical to obtaining a high optical quality connector. Make sure that your hands and the work area are as clean as possible to minimize the ingress of dirt into the connector parts.

408–3.8.10.1.1 Cable and Fiber Preparation

Step a – Ensure the OFCCs are the correct type as specified on the applicable cable diagram.

Step b – Measure the OFCCs to the required length. Then add sufficient slack to allow for at least two reterminations [40 mm (1.60 inches) of slack should be sufficient for one retermination].

Step c – Clean the OFCC outer jackets with a wipe dampened with alcohol and blow them dry with air.

NOTE

Keep the cable and connector parts free from oil, dirt, and grease throughout the installation procedure. If cleaning is necessary, use a wipe dampened with alcohol and blow the parts dry with air.

Step d – Feed each OFCC into a crimp sleeve and slide the sleeve back from the end of the OFCC.

NOTE

Only use crimp sleeves intended for termini. Do not use crimp sleeves intended for other types of connectors. The standard crimp sleeve for the terminus may be oriented in either direction.

Step e – Remove the OFCC jackets back 30 mm (1.20 in) from the end of the fiber using the OFCC stripper and trim the OFCC kevlar using the kevlar shears so that approximately 3 mm (0.12 in) extends past the OFCC jacket.

WARNING

Wear safety glasses when removing the fiber buffer and coating to avoid possible eye injury.

Step f – Remove the fiber buffers and coatings back 19 mm (0.75 in) from the end of the fiber using the buffer stripper. Remove the buffer and coating in small sections (approximately 6 mm (0.25 in) at a time).

NOTE

Normally, the buffer and coating are tightly adhered to one another and come off of the fiber at the same time.

CAUTION

The uncoated fiber is in its most vulnerable state. Take extreme care not to damage the fiber.

Step g – Remove any residual coating material from the bare fibers with a wipe dampened with alcohol. Wipe only once from the end of the buffer towards the end of the fiber.

NOTE

Do not repeatedly wipe the bare fiber as this will weaken the fiber.

408–3.8.10.1.2 Installation of Termini onto Fibers. This procedure describes the process for installing ceramic termini onto either multimode or single-mode fibers. The termini use epoxy to secure the fiber and a crimp sleeve to capture the kevlar strength members of the OFCC’s.

Step a – Turn on the curing oven so that it attains the proper temperature before the termini are placed within it (approximately 20 minutes).

Step b – Inspect the terminus and verify that the ferrule hole is free and clean of dirt. This can be accomplished by holding the front of the terminus up to a light and verifying that the light is visible from the rear of the terminus. If light cannot be seen through the terminus, push music wire through the terminus hole to clear it. Then blow dry air through the hole to remove any debris.

Step c – Remove the divider from a 2–part epoxy package and mix the two parts together until the epoxy is a smooth uniform color (see Figure 408–3–92). The epoxy can be mixed by either repeatedly rolling the divider over the package or gently sliding the divider over the package.

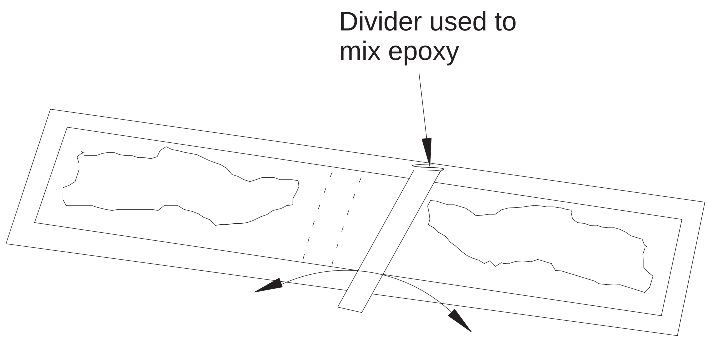

Figure 408–3–92. Mixing the Epoxy

NOTE

Verify that the epoxy shelf life has not expired. Do not use epoxy with an expiration date that has passed.

NOTE

Alternatively, the epoxy may be mixed by massaging the epoxy package by hand.

CAUTION

Do not introduce large air bubbles into the epoxy during the mixing process. Large air bubbles in the epoxy can lead to connector failure during temperature extremes.

Step d – Install the syringe tip on the syringe, remove the plunger, and squeeze the epoxy into the syringe. Replace the plunger.

WARNING

Wear safety glasses while dispensing the epoxy to avoid possible eye injury.

Step e – Remove air pockets in the syringe by holding the tip of the syringe upward and dispensing epoxy onto a wipe until it runs free and clear.

Step f – Slide the terminus, rear first, onto the syringe tip (see Figure 408–3–93). Keeping the syringe vertical, depress the plunger and slowly inject epoxy into the terminus until it escapes out of the ferrule, forming a very small bead.

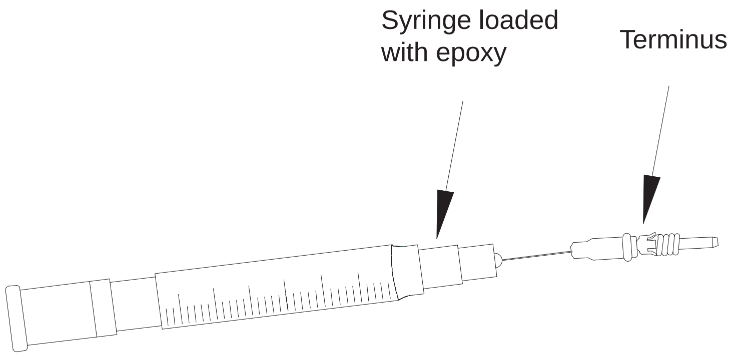

Figure 408−3−93. Injecting Epoxy into the Terminus

NOTE

Do not overfill. Be extremely careful not to get epoxy on the pin spring or other terminus moving parts.

Step g – Withdraw the syringe from the terminus. Maintain some pressure on the plunger as the syringe is withdrawn so that the terminus is completely filled with epoxy. Using a wipe dampened with alcohol, wipe away any epoxy on the outer diameter of ferrule without disturbing the epoxy bead.

NOTE

Alternatively, the terminus may be completely filled by maintaining a light pressure on the syringe plunger and allowing the epoxy to push the terminus off of the syringe tip.

Step h – Feather the kevlar evenly around the fiber and insert the fiber into the rear of the terminus (see Figure 408–3–94). Gently work the fiber through the terminus until the buffer seats against the rear of the ferrule. The OFCC jacket should come up to the rear of the terminus and the kevlar should surround the rear of the terminus. Once inserted, do not allow the fiber to slip back.

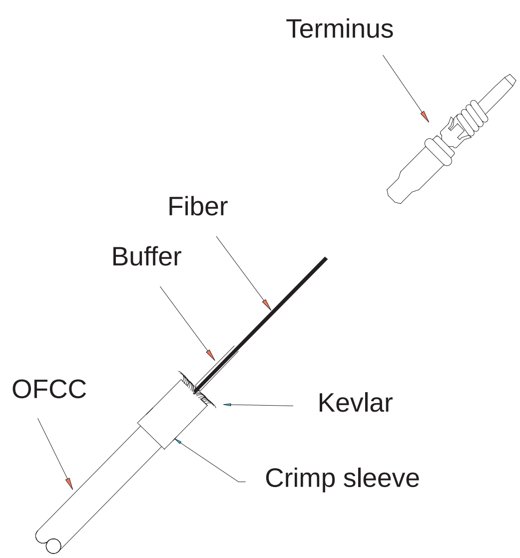

Figure 408−3−94. Inserting the Fiber into the Terminus

Step i – Slide the crimp sleeve over the kevlar and crimp it to the rear of the terminus using the crimp tool.

NOTE

A small amount of epoxy may be added on the kevlar near the rear of the terminus before the crimp sleeve is installed. However, no epoxy should be visible once the crimp sleeve is installed.

Step j – Verify that the kevlar does not protrude excessively from under the crimp sleeve. Excessive kevlar protrusion will cause the terminus to not seat properly in the finished connector. If excessive kevlar protrudes from under the crimp sleeve, trim it back using a razor blade.

Step k – Verify that there is a small amount of epoxy around the fiber where it protrudes from the ferrule. If it is found that there is no small bead of epoxy on the terminus tip, carefully add a small amount of epoxy around the fiber.

NOTE

There should only be a small amount of epoxy around the fiber to support it later during the polishing process. If too much epoxy is around the fiber during the curing process it may cause the fiber to crack.

Step l – Using a wipe dampened with alcohol, carefully wipe away any excess epoxy on the fiber that is more than 2 mm (0.08 in) from the ferrule tip surface.

Step m – Insert the terminus into the cure adapter until it snaps into place (see Figure 408–3–95).

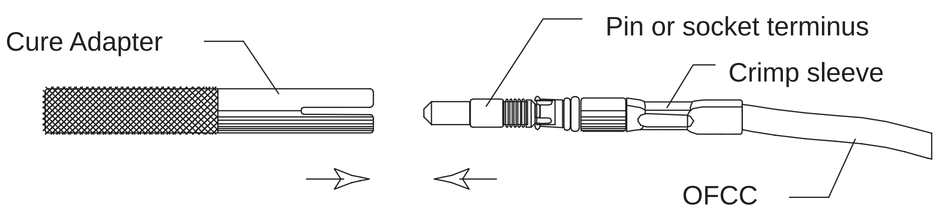

Figure 408–3–95. Inserting a Terminus in a Cure Adapter

Step n – Repeat steps b through m for each fiber to be terminated.

Step o – Place the cure adapters in the curing oven, and position the cable vertically over the oven using the cable stand, cable stand ring and cable clip (see Figure 408–3–96). Cure the epoxy for a minimum of 10 minutes (maximum of 30 minutes) at 120°C (248°F).

NOTE

When the cable is positioned above the terminus, make sure that no bends are placed in the OFCCs. Each OFCC should enter the terminus parallel to the terminus.

Step p – Turn the curing oven off and remove the cure adapters and termini from the curing oven. Allow the cure adapters and termini to cool for approximately 4 minutes.

408–3.8.10.1.3 Polishing the Fiber Ends. Hand polishing is the preferred method of polishing termini. Only procedures for hand polishing are contained herein.

NOTE

The procedures contained herein should produce an optical terminus with a physical contact (PC) polish.

WARNING

Wear safety glasses when scoring the fiber to avoid possible eye injury.

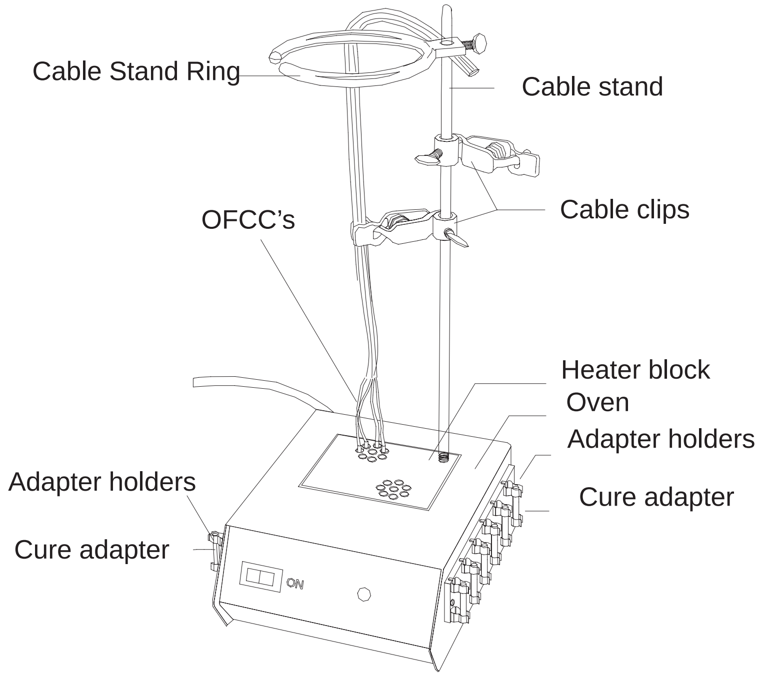

Figure 408–3–96. Termini in the Curing Oven

Step a – Remove the terminus from the cure adapter and score the fiber close to the terminus tip at the epoxy interface using one short light stroke with cleaving tool (see Figure 408–3–97). Pull off each fiber with a gentle, straight pull. Deposit the waste fiber in a trash container.

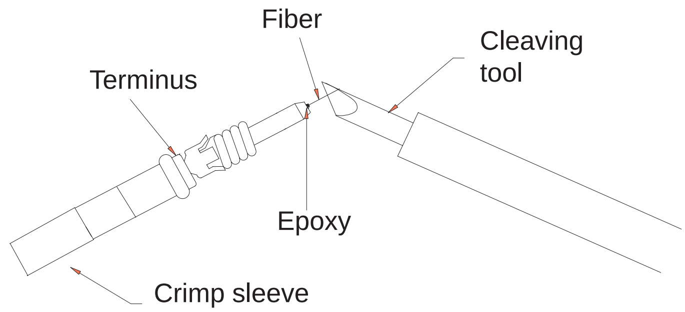

Figure 408–3–97. Scoring the Fiber

NOTE

Do not break the fibers with the cleaving tool.

NOTE

The termini not being polished should be left in the cure adapters during the polishing process to protect the fibers from breakage.

NOTE

Before inserting the terminus into the polishing tool, the terminus may be held vertically and the end of the fiber polished off by lightly running the 5 µm polishing paper over the top of the terminus tip. (This is referred to as air polishing the terminus.)

Step b – Rotate the top half of the polishing tool 90 degrees counterclockwise and separate the top from the base.

Step c – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–98).

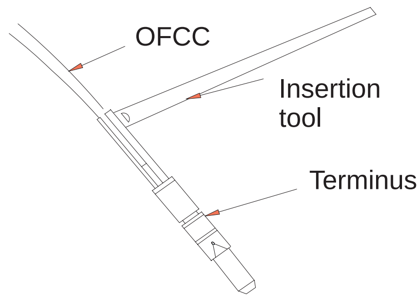

Figure 408–3–98. Placing the Terminus in the Insertion Tool

Step d – Insert the terminus into the center of the polishing tool top. Apply pressure with the insertion tool until the terminus snaps into place. Remove the tool by pulling straight back (see Figure 408–3–99).

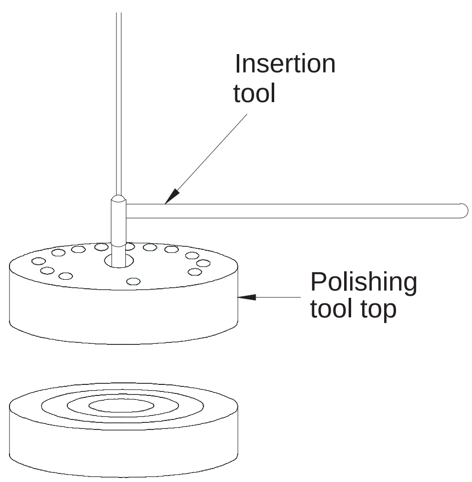

Figure 408–3–99. Inserting the Terminus into the Polishing Tool

NOTE

Difficulty in inserting the terminus into the polishing tool may indicate epoxy on outside of the terminus which must be removed before proceeding.

Step e – Install the top half of the polishing tool on the bottom half and rotate it clockwise (90 degrees) until it locks in place.

Step f – Clean the glass polishing plate, the backs of the polishing papers, and the surface of the polishing tool using a wipe dampened with alcohol. Blow all of the surfaces dry with air.

Step g – Place the 5 μm polishing paper on the glass plate and start polishing the terminus with very light pressure (the weight of the tool) using a figure–8 motion. Do not overpolish the terminus. Since the polishing time varies with the amount of epoxy present on the tip of the terminus, inspect the terminus tip frequently. Whenever the polishing tool is lifted, remove the grit from the tool and the terminus with air. When polishing is complete, clean the terminus and the polishing tool using a wipe dampened with alcohol and blow them dry with air. Perform a rough inspection of the ferrule end using the eye loop.

NOTE

The first polish is complete when all of the epoxy is gone from the tip of the terminus.

Step h – Replace the 5 μm paper with the 1 μm paper. Wet the paper and polish the terminus with very light pressure using a figure–8 motion for 10 to 20 complete motions.

Step i – Rotate the top of the polishing tool counterclockwise (90 degrees) and separate the top from the base. Insert the terminus removal tool into the bottom of the terminus cavity of the polishing tool top and press on the hilt of the removal tool until the tool clicks into place (see Figure 408–3–100). Depress the plunger and slide the terminus out of the polishing tool. Clean the terminus and the polishing tool with a wipe dampened with alcohol and blow them dry with air.

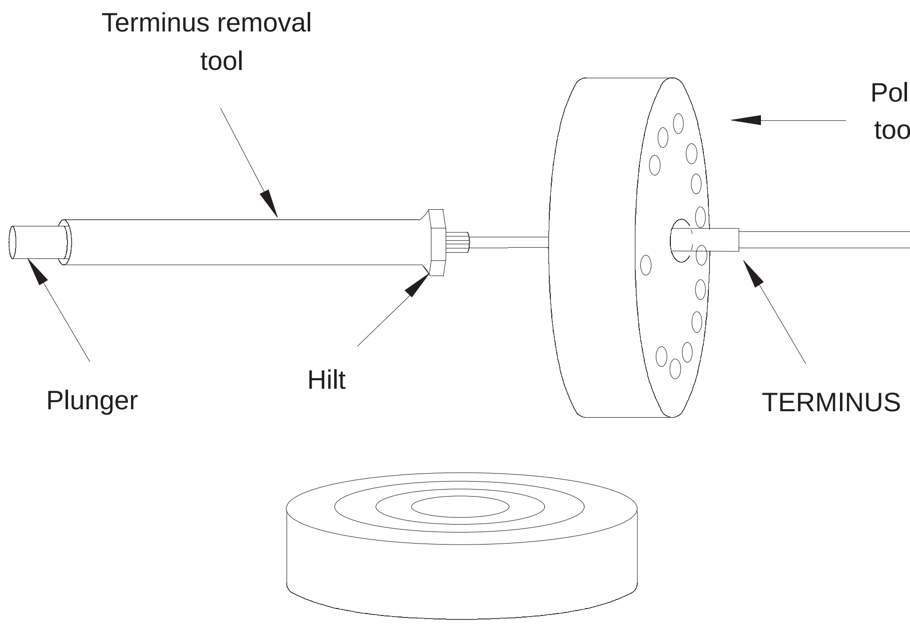

Figure 408–3–100. Removing the Terminus from the Polishing Tool

Step j – Repeat steps a through i for all of the termini.

408–3.8.10.1.4 Quality Check. Examine the terminus with the optical microscope to ensure that the optical surface is smooth and free of scratches, pits, chips, and fractures. If any defects are present, repeat steps 408–3.8.10.1.3 b through f, h, and i or reterminate the fiber (see Figure 408–3–101).

NOTE

Overpolishing the fiber will increase the optical loss of the terminus. Do not polish the terminus more than necessary to pass the quality check.

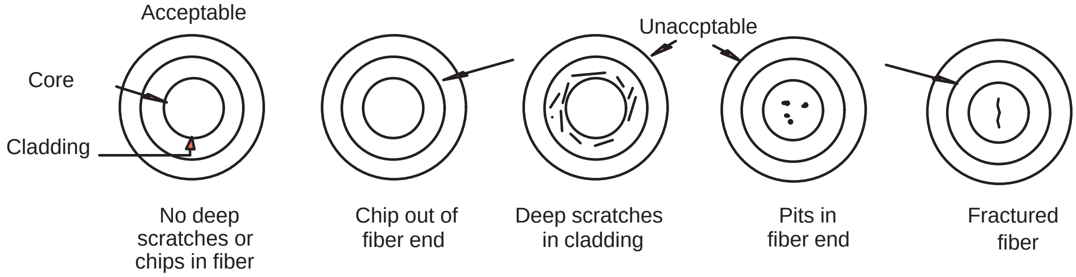

Figure 408−3−101. Quality Check

NOTE

A high intensity back light may be used to further illuminate fiber.

408–3.8.10.1.5 Installation of Terminus into Connector Insert

Step a – Place the end of the terminus insertion tool at the rear of the crimp sleeve with the OFCC laid in the tool channel (see Figure 408–3–102).

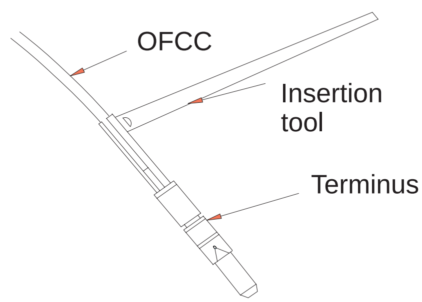

Figure 408−3−102. Placing the Terminus in the Insertion Tool

Step b – Place the terminus in the proper cavity in the rear of the connector insert. Apply pressure with the insertion tool until the terminus snaps into place (see Figure 408–3–103). Remove the tool by pulling straight back.

NOTE

A properly inserted terminus will have some axial “play” within the insert cavity.

NOTE

A socket terminus, unlike a pin terminus, will require installation of the alignment sleeves after seating the terminus.

Step c – Proceed to step d below for socket termini. For pin termini repeat steps a and b for the rest of the termini.

Step d – Place the end of the socket terminus alignment sleeve installation and removal tool into the solid end of the alignment sleeve, depress the plunger to grasp the alignment sleeve, and press the sleeve into the socket

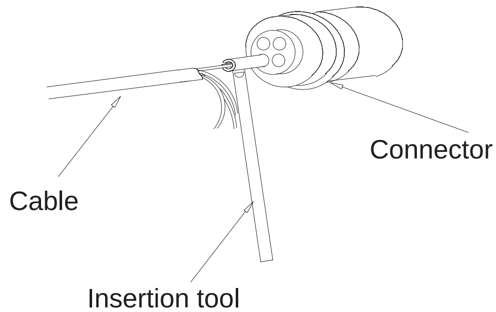

Figure 408–3–103. Installing the Terminus into the Insert

terminus cavity in the face of the insert (see Figure 408–3–104). Press until the sleeve snaps onto the groove on the ceramic terminus body. Remove the tool by releasing the plunger and pulling straight back. Proceed to step e below.

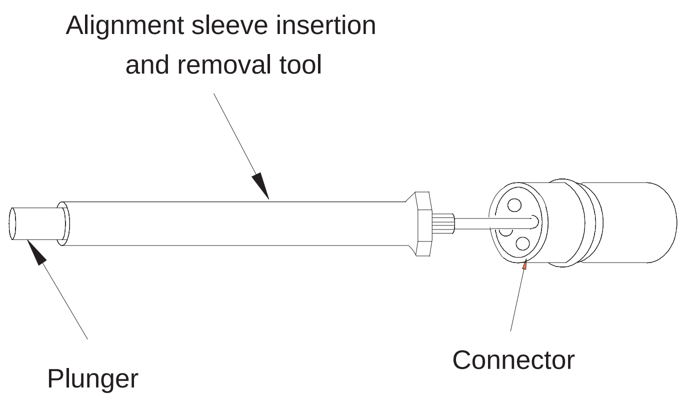

Figure 408–3–104. Installing the Alignment Sleeve

CAUTION

Do not rotate the tool after the sleeve is installed in the insert.

Step g – Repeat steps a through d for all of the termini.

408–3.8.10.1.6 Removal of Termini from the Connector Insert

NOTE

Perform this procedure only if the termini are to be removed from the connector.

NOTE

Proceed to step a below for socket termini. Proceed to step b below for pin termini.

CAUTION

Do not rotate the tool while the sleeve is in the insert.

Step a – Remove the alignment sleeves from the socket termini using the terminus alignment sleeve installation and removal tool by inserting the tool end into the alignment sleeve and depressing the plunger so that the tool grasps the sleeve lip. Pull the sleeve straight back. Proceed to step b.

Step b – Insert the terminus removal tool into the terminus cavity from the front of the insert and press on the hilt of the tool until it snaps into place (see Figure 408–3–105). Depress the plunger to slide the terminus out the rear of the insert.

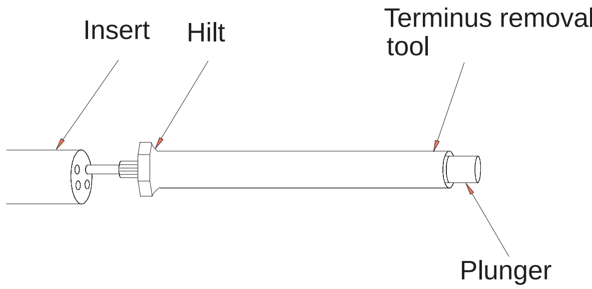

Figure 408–3–105. Removing the Terminus from the Insert

408–3.9 CABLE PENETRATIONS OF SHIP STRUCTURE

408–3.9.1 Metal stuffing tubes shall be used for fiber optic cable penetrations of ship structure. Metal stuffing tubes shall be in accordance with MIL–S–24235. The methods for installation of the metal stuffing tubes are the same as those specified for electrical cables in DOD–STD–2003. Refer to Appendix B for stuffing tube sizes for fiber optic cables. The following are excerpts from DOD–STD–2003 and MIL–STD–2042–4(SH) regarding sealing and tightening.

408–3.9.1.1 Cable penetrations of vertical non-tight structures within a compartment need not be sealed at intervals closer than 20 feet horizontally. However, if one penetration on the structure requires sealing, then all penetrations of that structure shall be sealed.

408–3.9.1.2 Plastic sealer, type HF as specified in MIL–I–3064 shall be used to seal the space around the cables in collars or nipples used for passing cables through light tight and fume tight bulkheads.

408–3.9.1.3 Size of the stuffing tube groups shall be limited to permit tightening of gland nuts in the group using stuffing tube wrench set type II, class I, style A, form B in table IV of GGG–W–646. Penetration spacing shall be as specified in Design Data Sheet DDS 100–2.

408–3.9.1.4 Fiber optic cable may lose some of its resiliency after being compressed. To ensure a watertight seal is achieved and maintained, re-tighten the cap on the stuffing tube (or the bolt, if a multiple cable penetrator(s) is being used), approximately 24 hours after initial compression.

408–3.10 CABLE ENTRY AND ROUTING WITHIN EQUIPMENTS

408–3.10.1 STUFFING TUBES. This section describes the procedures for fiber optic cable entry to equipment through stuffing tubes.

408–3.10.1.1 Cable penetrations into equipment shall be made using nylon stuffing tubes or integral multiple cable penetrators in accordance with MIL–STD–2042–2(SH). Nylon stuffing tubes and packing assemblies shall be in accordance with MIL–S–19622. Refer to MIL–STD–2042–2(SH) and DOD–STD–2003 for additional nylon stuffing tube installation information.

408–3.10.2 CABLE ENTRY INTO EQUIPMENT BY WAY OF NYLON STUFFING TUBES. The equipment and Table 408–C–13 (Appendix C) as applicable shall be used to perform this procedure.

408–3.10.2.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers.

2. Do not touch the ends of bare fiber as they may be razor sharp. Wash your hands thoroughly after handling bare fibers.

3. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

408–3.10.2.2 Tube and Cable Installation

NOTE

Packing assemblies and “O”-rings are not furnished with stuffing tubes. They must be ordered separately by the installing activity to suit installations.

Step a – Select the stuffing tube, packing and O-ring in accordance Table 408–C–14 and Table 408–C–15 (Appendix C).

WARNING

Wear safety glasses during deburring to avoid possible eye injury.

Step b – Inspect the hole in the enclosure and remove any burrs or irregularities using the deburring tool.

Step c – For steel enclosures where the roughness is greater than a 125 microinch finish (not required on aluminum enclosures), remove the paint using a paint scraper and clean the surface with emery paper approximately 0.5 inch (13 mm) wide around the hole on the exterior of the enclosure. Apply one coat of primer, and allow to set. Dust coat the surface with talc if the primer is not thoroughly dried at the time of the tube installation. Remove the cover and proceed to step d, e or g below, as applicable.

Step d – With straight tubes, insert the stuffing tube body into the hole from the inside of the enclosure (see Figure 408–3–106). If necessary, remove the interior fitting from enclosure. Proceed to step f below.

Step e – With “Y” and angle tubes, insert the stuffing tube body into the hole from the outside of enclosure (see Figure 408–3–107 and Figure 408–3–108). The excess length protruding into the enclosure may be removed.

Step f – Screw the locknut onto the body and tighten with a wrench against the “O”-ring sufficiently to obtain plastic to metal contact of the stuffing tube and the enclosure. In cases where this plastic to metal contact cannot be obtained, tighten the locknut until the threads start to skip. This is considered a satisfactory indication of tightness. Proceed to step h below.

NOTE

Hold the stuffing tube body while tightening the locknut to prevent turning.

Step g – With NPT tubes, screw the tube into the enclosure pipe thread and tighten it sufficiently to obtain a seal at the threads (see Figure 408–3–109).

Step h – Measure the length of the cable jacket to be removed:

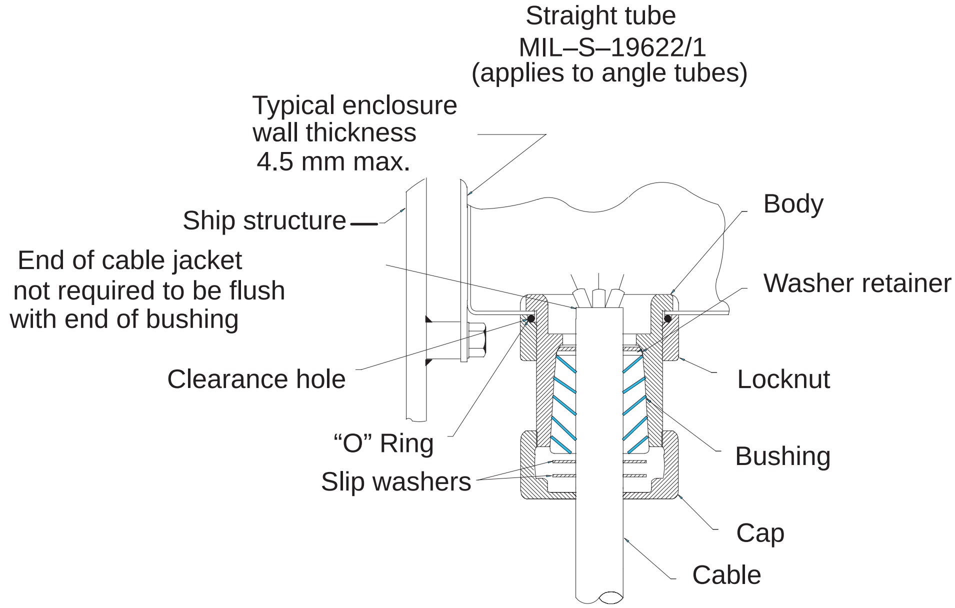

Figure 408–3–106. Straight Tube

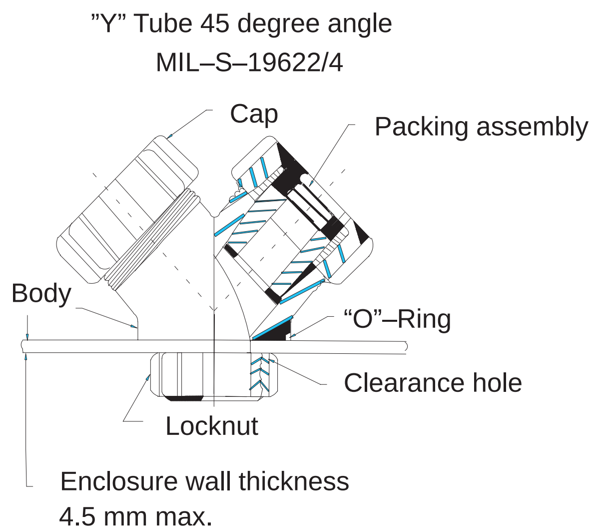

Figure 408–3–107. "Y" (45°) Tube

For unterminated cables, measure the distance required to route OFCCs from innermost portion of the stuffing tube completely around the interior of the interconnection box (or to the furthermost connection point in the end user equipment), add approximately 127 mm (5 inches) and mark cable outer jacket.

For terminated cable assemblies, measure the distance required to route OFCCs from innermost portion of the stuffing tube to the furthermost connection point in the equipment, add approximately 76 mm (3 inches) and mark cable outer jacket. In an interconnection box the distance measured shall be great enough that the OFCC can be routed one-half of the way around the box and then to the termination point.

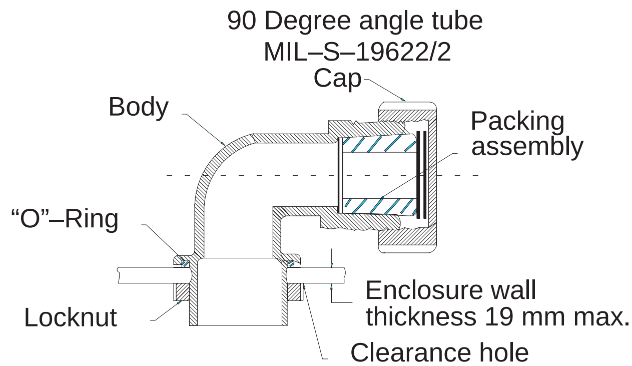

Figure 408–3–108. 90° Angle Tube

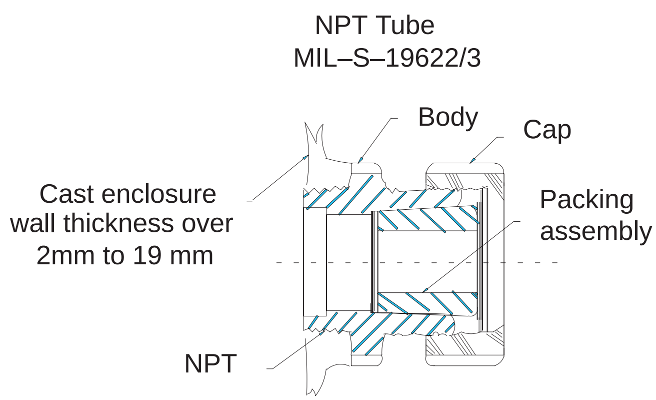

Figure 408–3–109. NPT Tube

Step i – Slide the stuffing tube parts onto cable in the order indicated:

1. Cap
2. Two slip washers
3. Rubber bushing
4. Bottom washer

Step j – Slide the parts up the cable beyond the mark and, if not already done, remove the outer jacket up to the mark using the cable stripper.

CAUTION

Do not cut or nick OFCC’s.

Step k – Cut off the cable kevlar strength members and exposed central member, if present, using kevlar shears.

NOTE

If cable strength member capture is planned, leave approximately 102 mm (4 inches) of the kevlar strength members protruding from the cable jacket.

Step l – Remove the waterblocking material and clean the OFCC's using a wipe dampened with alcohol. Blow dry with air.

Step m – Insert the cable through the stuffing tube and into the enclosure so that the outer jacket protrudes 12 mm to 25 mm (0.5 in to 1 inch) inside the equipment. Slide the washers and bushing down the cable into the tube.

NOTE

When necessary to pass an airtight test, apply RTV silicone rubber to the bushing.

Step n – Slide the cap down the cable, screw it onto the tube and tighten it sufficiently using the spanner wrench to compress the bushing to form a tight seal between the cable and the tube.

NOTE

Hold the tube body when tightening the cap to prevent breaking the watertight seal.

Step o – After the bushing has been compressed for approximately 24 hours, retighten it to ensure the seal is maintained.

Step p – If required, wind the exposed kevlar strength member under a screw lug attached beside the stuffing tube and tighten the screw lug.

NOTE

This step is only performed when additional strain relief is required beyond that provided by the stuffing tube assembly.

NOTE

Sealing plugs are used to seal nylon stuffing tubes from which cables have been removed. When installing sealing plugs, the cable bushing shall be discarded but the nylon washers shall be retained and left in the stuffing tube.

Step q – Install connectors or splice ferrules on the OFCCs as specified on the system drawings using the methods specified in this manual.

408–3.10.3 EQUIPMENT CABLE ENTRY BY WAY OF INTEGRAL MULTIPLE CABLE PENETRATORS (MCP). This method describes a procedure for fiber optic cable entry to fiber optic equipment through multiple cable penetrators (MCP) integral to the equipment being entered. The equipment and materials in Table 408–C–16 (Appendix C) shall be used to perform this procedure.

408–3.10.3.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers.
2. Do not touch the ends of bare fiber. Wash hands thoroughly after handling bare fibers.
3. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

408–3.10.3.2 Cable Installation

Step a – Select MCP blocks in accordance with Table 408–B–10 (see Appendix B).

Step b – Measure the length of the cable jacket to be removed:

For unterminated cables, measure the distance required to route OFCCs from innermost portion of the MCP completely around the interior of the interconnection box (or to the furthermost connection point in the end user equipment), add approximately 127 mm (5 inches) and mark the cable outer jacket.

For terminated cable assemblies, measure the distance required to route OFCCs from innermost portion of the MCP to the furthermost connection point in the equipment, add approximately 76 mm (3 inches) and mark the cable outer jacket. In an interconnection box the distance measured shall be great enough that the OFCC can be routed one-half of the way around the box and then to the termination point.

Step c – Remove the outer jacket up to the mark using the cable stripper.

CAUTION

Do not cut or nick OFCC's.

Step d – Cut off the cable kevlar strength members and exposed central member, if present, using kevlar shears.

Step e – Remove the waterblocking material and clean the OFCC's using a wipe dampened with alcohol. Blow dry with air.

CAUTION

Do not exceed the cable minimum bend diameter of eight times cable O.D. for short term bends and sixteen times the cable O.D. for long term bends.

Step f – Feed the cables into the interconnection box or the other equipment through the cable penetration opening.

Step g – Liberally apply tallow to the outside portion of the insert blocks, the inner portion of the MCP frame and to the sides of the wedgepack. Make sure that tallow is placed in the corners of the MCP frame.

NOTE

The wedgepack may be removed and disassembled to apply the tallow.

Step h – Reinstall the wedgepack (if removed) and install the insert blocks on the cables so that the outer jacket protrudes 13 mm (0.5 inch) to 25 mm (1 inch) inside the equipment. Install the cable insert blocks so that the gap between the insert block halves is parallel to the wedge pack. Install the insert blocks into the MCP frame so that the insert blocks are flush with the outside edge of the MCP frame. Fill all positions in the frame with insert blocks [either cable insert blocks or blanking (solid) insert blocks (see Figure 408–3–110)].

NOTE

Incoming cables may be installed on one end of the enclosure and outgoing cables on the opposite end for large enclosures. Where only one penetrator is used, incoming cables may be installed on one side of the wedgepack and outgoing cables on the opposite side.

Step i – Tighten the nut on the wedgepack to compress the insert blocks in the frame using a wrench. Tighten the wedgepack nut until the outside wedge pack metal plate is almost flush with the bottom of the MCP frame and the insert blocks. Continue to tighten the wedgepack nut until a torque between 5.7 and 16.9 N–m (50 and 150 in–lbs) is reached.

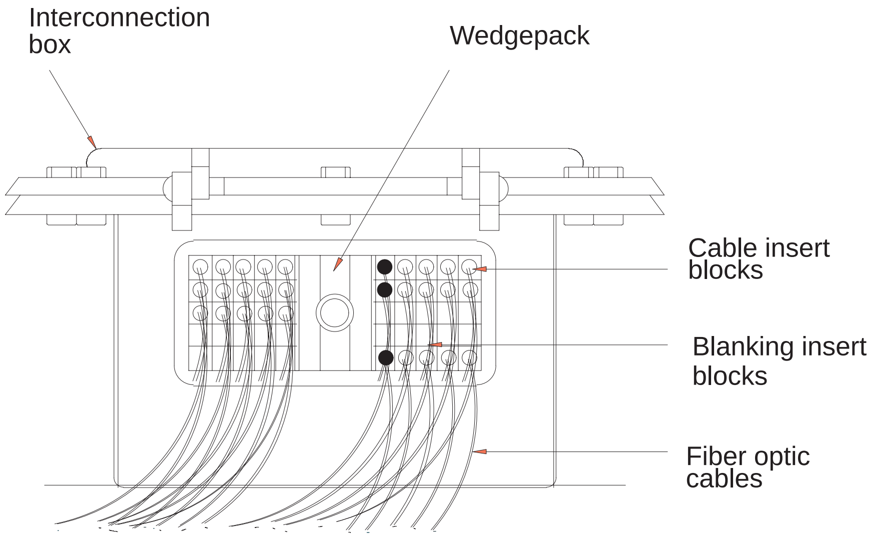

Figure 408–3–110. Interconnection Box Integral MCP-(typical)

NOTE

The wedge pack is fully tightened when the length of the pack is the same as the depth of the MCP frame.

Step j – After the blocks have been compressed for approximately 24 hours, retighten the nut to ensure that the seal is maintained.

Step k – Install connectors or splice ferrules on the OFCCs as specified on the system drawings using the methods specified in this manual.

408–3.10.4 CABLE AND BUFFERED FIBER FORMING AND SHAPING. This method describes a procedure for the forming and shaping of the optical fiber cable components (OFCC) and buffered fibers within the interconnection box and installation of connectors and splices in patch panels and splice trays, respectively. The equipment and materials Table 408–C–17 (Appendix C) shall be used to perform this procedure.

408–3.10.4.1 Safety. The following safety precautions shall be observed:

1. Safety glasses shall be worn at all times when handling bare fibers.

2. Do not touch the ends of bare fiber. Wash hands thoroughly after handling bare fibers.

3. Do not stare into the end of a fiber until verifying that the fiber is not connected to a laser light source or LED.

CAUTION

Throughout the fabrication process, cleanliness is critical to obtaining a high optical quality connector or splice. Make sure that your hands and the work area are as clean as possible to minimize the ingress of dirt into the connectors and splices.

408–3.10.4.2 Forming and Shaping

Step a – Verify that the cable entrance procedures of this manual have been completed.

Step b – Open the enclosure cover and visually examine the OFCC's for cuts, nicks, kinks or twists before forming them into groups.

CAUTION

Do not exceed the bend diameter of eight times the OFCC O.D. for short term bends and sixteen times the OFCC O.D. for long term bends.

Step c – Observe the connection configuration chart or other approved drawing and form the fibers into groups based on their final destination. Groups may then be formed into bundles and shaped using lacing or self-clinching straps in accordance with DOD–STD–2003–1, Figures 1B5 and 1B6 respectively. Lace or strap the groups loosely; do not tighten down the straps with the hand tool.

Step d – Route the fiber bundles around the box securing them to the box mounting brackets using the self-clinching straps. Observe the following during routing (see Figure 408–3–111):

1. All OFCCs shall be routed one-half of the way around the box and then to the termination point.

2. When a direct route to a termination point would exceed the OFCC long term bend diameter of sixteen times the OFCC O.D., an indirect route shall be used.

3. Groups and bundles shall not cross the splice trays or patch panels or in any other way obstruct access to the individual connectors, splices or adapters. Groups and bundles may be routed between the splice tray or connector patch panel modules, if necessary.

4. Groups and bundles shall be protected from possible damage by sharp edges by the use of supporting brackets or by synthetic tubing at the point of the sharp edge.

Step e – Break out each separate OFCC from the group or bundle and, if not already done, slide the heat shrink tubing with the fiber identification over the connector or splice onto the OFCC cable jacket.

NOTE

The heat shrink tubing should normally be pushed up the OFCC before the OFCC is terminated. If the heat shrink is not put on before the connector or splice, heat shrink may be available that can be installed after the connector or splice is installed.

NOTE

Do not install heat shrink tubing on 900 micron fibers. In those cases where 900 micron fiber is present going into a splice, the tubing should be installed in a region where there is an OFCC.

CAUTION

Do not overheat the OFCC. Prolonged exposure of the OFCC jacket to temperatures in excess of 160 degrees Celsius (°C) [320 degrees Fahrenheit (°F)] may damage the OFCC jacket. Discontinue heating of the tubing and allow the OFCC jacket to cool before reheating if the OFCC jacket shows any signs of bubbling.

Step f – Holding the heat gun approximately 102 mm (4 inches) away from the OFCC and tubing, shrink the tubing.

Step g – Form the unterminated OFCC bundles into a loop around the complete interior of the box being careful not to kink or otherwise damage the OFCCs and end seal the bundles in accordance with MIL–STD–2042–1. Tie off the unterminated bundles such that they will not obstruct access to other components.

NOTE

Do not group or bundle the unterminated OFCCs with the terminated OFCCs. Unterminated OFCCs should be independently grouped, bundled and strapped to the box mounting brackets from the terminated OFCCs.

Step h – Install the connectors in the patch panels or install the splices in the splice trays as described in this manual.

408–3.10.4.3 Connector Installation in the Patch Panel

Step a – Unscrew the two screws holding the patch panel and pull the panel forward until it catches in the slide.

NOTE

The panel can be completely removed by pulling it through the catch.

NOTE

Use a wipe dampened with alcohol to clean all connectors and blow them dry with air before making connections.

Step b – Insert one connector into the adapter mounted in the patch panel and lock it into place with the bayonet fitting. (This is accomplished by aligning the key on the connector barrel with the keyway on the adapter, inserting the connector in the adapter, engaging the bayonet coupling mechanism and rotating the connector clockwise until it stops.)

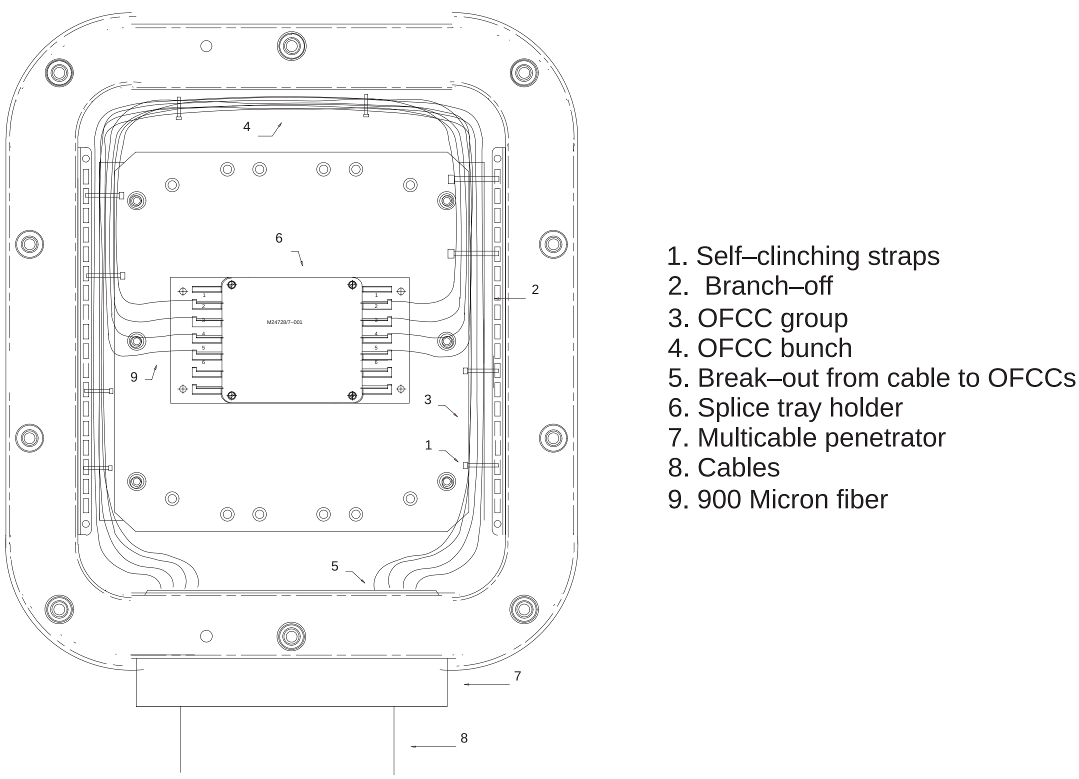

Figure 408–3–111. Forming and Shaping - (typical)

Step c – Insert the mating connector into the opposite side of adapter and lock it into place.

Step d – Repeat steps b and c above until all of the connectors are installed. Push the panel back into the box and tighten the screws.

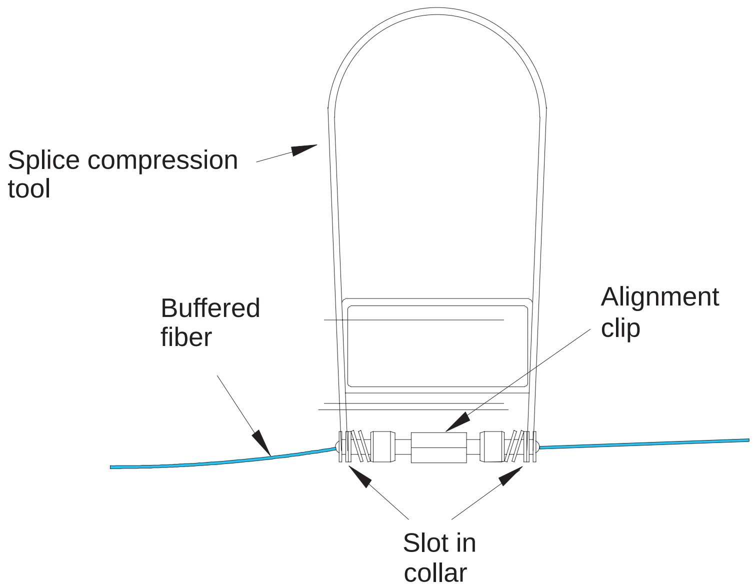

Figure 408–3–112. Compressing Ferrule Springs

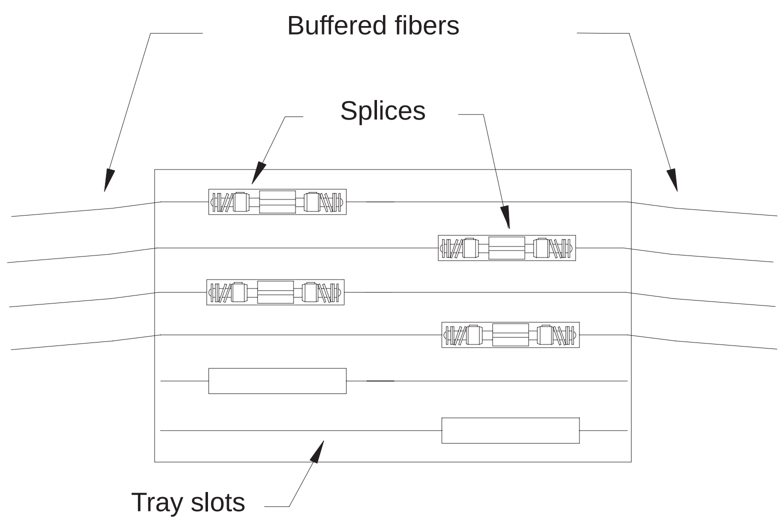

Figure 408–3–113. Splices Installed in Splice Tray – (typical)

Step e – Close and secure the cover.

408–3.10.4.4 Splice Installation in the Splice Tray

Step a – Unscrew the four screws holding the splice tray holder cover and remove the splice tray cover. Pull the splice tray forward and remove it from the holder.

NOTE

If the splice tray is deformed from being installed in the splice tray holder, obtain and use a new splice tray for the installation.

Step b – Place the ends of splice compression tool into the slots on the splice ferrule collars and squeeze the tool to compress the ferrule springs (see Figure 408–3–112).

Step c – Carefully place the splice into the splice tray with the open slot in the splice alignment sleeve facing upward (see Figure 408–3–113). Ensure the ferrule ends are completely inside the tray and that the buffered fibers are carefully routed in the tray slots.

Step d – Repeat steps b and c above until all of the splices are installed in the tray. Place the splice tray cover over the splice tray and reinstall the tray into the holder. Repeat the above procedures for each tray, as required.

Step e – Replace the tray holder cover and tighten the holder cover screws.

Step f – Close and secure the enclosure cover using a wrench.

408–3.10.5 ATTACHING FIBER CABLE INSIDE CABINETS. Inside the cabinet refers to any fiber optic cable or harness that occurs within the cabinet including connections between modules, backplanes, racks/drawers, front panel, and cabinet bulkheads. Any two or more of these may be interconnected via single or multi-fiber cable harness assemblies. Fiber attachment inside cabinets should be performed as specified in the equipment or cabinet manual. If the equipment or cabinet manual does not specify fiber attachment methods, the following general guidelines shall be followed.

408–3.10.5.1 Strain Relief. Within a cabinet, strain relief mechanisms are necessary to assist in relieving stress points and protect points of probable damage on the fibers. These stress points are usually where the fiber is undergoing a bend, passing over a sharp edge or object, or flexing continuously. Another stress point is where individual OFCCs are broken out from a multifiber cable and routed to cabinets, drawers, and modules. OFCCs and cables that are not securely fastened will have a higher failure rate than OFCCs and cables that are securely fastened. Grasshopper clips, velcro, tie wraps, cable mounting brackets, clamps, bend limiters, and mechanical channels are used as strain relief mechanisms. Care shall be taken to ensure excessive stress is not placed on the individual fibers or OFCCs. All OFCCs within a drawer shall be fastened at six to twelve inch intervals; cable harnesses inside a cabinet shall be fastened every one to two feet minimum.

408–3.10.5.1.1 Points most likely to experience fiber damage within cabinets are connectors, splices, component interfaces, and interface points. Each of the connectors has some sort of strain relief mechanism already designed in, such as a crimp sleeve for ST and terminus. The crimp sleeves in conjunction with the kevlar strength members of OFCCs relieve stress at the fiber to connector junction. Rotary mechanical splices do not contain crimp sleeves for strain relief and must be protected from environmental and other stress through the use of protective splice trays and other strain relief mechanisms.

408–3.10.5.2 Internal Cable Runs. Cable and harness runs internal to the cabinet are normally designed and routed with repair in mind. Cable runs should be placed so they will not hamper repair/maintenance efforts for other equipments in the cabinet, but should also be accessible for repair themselves. Internal fiber runs may safely be routed with wire harness runs but care shall be exercised to avoid putting excess strain on cable from bending, securing devices, or tensile loads applied when drawers/racks are opened or closed.

408–3.10.5.3 Slack Requirements. Fiber optic cables shall not be pulled tight. A small amount of slack shall be left in each harness run. If the cables are pulled too tight, stress will be placed on the fiber and breakage may occur.

408–3.10.5.4 Fastener Precautions. Fasteners used with fiber optic cables can cause many problems. Cable ties and other fastening devices shall be adjusted so that the cable is loosely held. Fasteners that are over-tightened will increase the fiber loss and can permanently damage the OFCCs. Securing options include a silicon sealer (RTV) to hold fiber in place, split foam rubber sleeves for the fiber with cable ties, and cable mounting clamps.

408–3.10.5.5 Inside and Outside Connections. All fiber optic connections from the cabinet to the outside shall be done through the front panel or bulkhead connectors, using only government approved parts. External bulkhead and front panel connectors shall be in accordance with MIL–C–28876. Connections within the cabinet shall be in accordance with MIL–C–83522/16 (ST type) or MIL–S–24623/4 (Rotary mechanical type).

408–3.10.5.6 Special Terminations Inside Cabinets. Special terminations may be required inside cabinets for module to backplane interconnections, optical backplane applications, or specialty front panel connector. Such terminations will be called-out within the cabinet equipment manuals.

APPENDIX A
GUIDE TO SPECIFICATIONS AND STANDARDS

408–A.1 MIL–STD–2042(SH), FIBER OPTIC TOPOLOGY INSTALLATION STANDARD METHODS FOR NAVAL SHIPS

408–A.1.1 GENERAL. MIL–STD–2042(SH) comprises the basic standard and six numbered parts. The basic standard is introductory in nature and only identifies the content and arrangement of each of the numbered parts. Each of the numbered parts addresses a separate functional topic and presents general information and detailed requirements relative to that topic. Table 408–A–1 identifies the topics covered by the individual numbered parts. The entire MIL–STD–2042(SH) is intended for use by the shipbuilder, primarily for new construction. It may however, be utilized during conversion or alteration of existing ships. Detailed methods presented in the numbered parts may also be helpful to the ship's force.

Table 408–A–1. MIL–STD–2042(SH)

DOD Standard Part Number	Topic
MIL–STD–2042(SH)–1	Cables
MIL–STD–2042(SH)–2	Equipment
MIL–STD–2042(SH)–3	Cable Penetrations
MIL–STD–2042(SH)–4	Cableways
MIL–STD–2042(SH)–5	Connectors and Interconnections
MIL–STD–2042(SH)–6	Tests

408–A.1.2 PART 1, CABLES. Part 1 provides general information regarding cable selection, identification, handling and stowage, and cable and fiber connections/terminations. Detailed requirements include methods for cable end sealing and cable jacket repair.

408–A.1.3 PART 2, EQUIPMENT. Part 2 provides general information regarding the Interconnection Box (IC) selection, location, mounting and marking. Methods of mounting IC boxes on ships structures are the same as those for electrical enclosures given in DOD–STD–2003–2. These methods are referenced rather than repeated in MIL–STD–2042(SH). Detailed requirements include methods for the following:

a. Cable entrance to equipment through nylon stuffing tubes and multiple cable penetrators (MCPs).

b. Cable forming and shaping within the IC box.

c. Installation of connectors in the patch panels and splices in the splice trays.

d. Splice assembly and alignment.

408–A.1.4 PART 3, CABLE PENETRATIONS. Part 3 provides general information regarding sealing requirements and methods for cables penetrating ships structures (Surface and Submarine). The proper methods for fiber optic cable penetrations are the same as those for electrical cables given in DOD–STD–2003–3. These methods are referenced rather than repeated. Part 3 does, however identify specific sizes of stuffing tubes and MCP insert blocks to be used with each fiber optic cable. Detailed requirements include methods for penetration using steel and aluminum stuffing tubes, MCPs, chafing collars and kickpipes.

408–A.1.5 PART 4, CABLEWAYS. Part 4 provides general information regarding location of cable runs (including survivability routing), protection of cable from mechanical and battle damage, and installation of cables in cableways. The cableway installation portion addresses cable slack, bend radii, double banking, cable retention and cable tagging. The detailed methods of cableway installation are the same as those for electrical cableways given in DOD–STD–2003–4. These methods are referenced rather than repeated. Detailed requirements include methods for installation of cableways on surface and sub-surface vessels and protection of cables from mechanical and environmental damage.

408–A.1.6 PART 5, CONNECTORS AND INTERCONNECTIONS. Part 5 provides general information for the selection, location, and installation of connectors and splices. Detailed requirements include methods for installation of single and multiple terminus connectors and mechanical splice ferrules.

408–A.1.7 PART 6, TESTS. Part 6 provides general information for test methods to be employed before, during, and after installation of the fiber optic topology. Also included is a description of test equipment, jumpers, and adapters used to conduct the tests. Detailed requirements include methods for the following:

a. Visual Inspections.

b. Cable Attenuation Tests.

c. Cable Assembly Link Loss Test.

d. Cable Attenuation Tests.

e. Cable Topology End-to-End Attenuation Tests.

f. Measurement Quality Jumper Cable Selection Test.

g. Heavy Duty Connector Mechanical Pull Test.

408–A.1.8 SYSTEM DESIGN STANDARD

MIL–STD–2052(SH) provides standard design requirements for digital fiber optic systems having data transmission rates not greater than 500 Megabits per second (Mbps) installed aboard U.S. Navy ships and submarines. Detailed requirements include information on component selection, special environmental considerations, cabinet organization, and equipment connections. Detailed equations and examples for the calculation of bandwidth, power budget and reliability are also included. MIL–STD–2052(SH) is primarily intended for the use of manufacturers and end user equipments and design engineers.

408–A.2 TOPOLOGY DESIGN HANDBOOK

408–A.2.1 GENERAL. MIL–HDBK–2051(SH), the fiber optic cable topology (FOCT) design handbook identifies specific design techniques and criteria for the development of the optimal FOCT configuration. Guidelines and topology rules ensure the FOCT will be capable of sustaining future growth, expansion and reconfiguration throughout the life of the ship. A review of FOCT component specifications is presented to identify options available as to cable and fiber type, terminations and IC box sizes and configurations. MIL–HDBK–2051(SH) is primarily intended for use by the FOCT design engineer.

APPENDIX B

DESIGN AND INSTALLATION CONSIDERATIONS

408–B.1 KEY INFORMATION FROM THE FIBER OPTIC CABLE TOPOLOGY DESIGN HANDBOOK.

408–B.1.1 GENERAL. Fiber optic cables contain more than one fiber and each fiber may carry information from a different user system. The fibers required for individual areas of a ship can be carried in one cable. This reduces the total number of cable runs and facilitates survivability during routing. The categories that fibers may be divided into are identified in Table 408–B–1.

408–B.2 SPARING, REDUNDANCY AND GROWTH WITHIN THE FIBER OPTIC CABLE TOPOLOGY

408–B.2.1 GENERAL. The fiber optic cable topology is designed to provide current user systems with increased reliability and survivability through sparing and redundancy. In addition, growth fibers provide a growth capacity for easy installation of new systems throughout the ship's life cycle.

408–B.2.2 SPARE FIBERS WITHIN A CABLE. Spare fibers should be incorporated in all fiber optic cable topology trunk cables, and in local cables which penetrate decks or bulkheads. These spare fibers are to be used to replace single fiber failures within the cable. Instances will occur where more than one cable connects the same two pieces of equipment such as a typical trunk group. In these instances, the spare fibers should be evenly distributed among all the cables instead of assigning all the spare fibers to the same cable.

408–B.2.3 REDUNDANT FIBERS. Redundant fibers are fibers which provide an alternate signal path in case the primary path is damaged.

408–B.2.4 REDUNDANT LOCAL FIBERS. Redundant local fibers may be provided between a user Equipment and one or two interconnection boxes as specified by the user system.

408–B.2.5 REDUNDANT TRUNK FIBERS. Redundant trunk fibers may be provided between interconnection boxes. These redundant paths are intended to allow manual reconfiguration of the terminations within the interconnection box to avoid damaged trunk paths. Primary and alternate fibers between interconnection boxes should be evenly distributed between the redundant paths to reduce the number of links affected should one of the trunk paths fail.

408–B.3 KEY INFORMATION FROM THE INSTALLATION STANDARD

408–B.3.1 CABLE STORAGE. Prior to actual shipboard installation, fiber optic cables should be stored in a dry environment, protected from the weather and limited to temperatures between –40°F to 160°F (–40°C to +71°C). They should be stored on reels of at least 24 times the cable outside diameter (O.D.). Cables should not be stored on hooks, dowels or pegs. When cables are stored or set aside for installation, they should be end sealed against moisture absorption as described in MIL–STD–2042–1(SH). A cable that has been in storage for one year or less may be installed if a visual inspection shows no mechanical damage has been sustained which might impair the watertight integrity of its outer jacket or the integrity of the optical fibers. Before use, cables stored over one year must also pass an attenuation test. The cables should then be carefully transported (avoiding crushing, twisting or kinking of the cable) to the installation site. Care should also be taken not to exceed the minimum bend diameter of not less than eight times the cable O.D. for short dynamic bends during installation, and 16 times the cable O.D. for long term static bends after installation.

408–B.3.2 INSTALLATION IN CABLEWAYS. Fiber optic cable installation in cableways is similar to that for electrical cable. However, some additional precautions are required to protect fiber optic cable from mechanical damage during installation. Mechanical devices are not used to pull fiber optic cable to avoid the kinking, twisting, sharp bending or stretching which can result when excessive force is applied.

Table 408–B–1. FIBER CLASSIFICATIONS

Classification	Trunk Fibers	Local Fibers
Allocated and Used	Primary Channels Alternate Channels Non–Redundant Channels (NRC)	Primary Channels Alternate Channels NRC
Allocated and Not Used	System Spares Topology Redundant Fibers	System Spares System Redundants System Growth
Unallocated	Topology Spares Growth Fibers	Spares (only if Cable Penetrates a Deck or Bulkhead)
Unused	Extra Fibers	Extra Fibers

408–B.3.2.1 Where fiber optic cables are to be mixed with electrical cables in the same cableway, the fiber optic cables are installed last, run on top of the electrical cables, and located in the center of the cableway. When installing cable in the cableway, feed the entire cable into position and then secure it in the cableway. Additional personnel may be required at several points along a lengthy cable route to avoid coils and kinks. Where installation of fiber optic cables into cableways containing armored cable cannot be avoided, additional personnel should be used during cable pulling to ensure the optic cable is not damaged by the armor.

408–B.3.2.2 Additional care shall be taken when handling and installing a cable when its temperature is 36°F (2°C) or lower. At such temperatures, the portion of the cable that must be bent during installation should be thoroughly warmed using a heat gun (or equivalent) before installing the cable in the cableway.

408–B.3.3 INTERCONNECTION BOX INSTALLATION. Unlike electrical boxes, fiber optic Interconnection boxes (with passive components) can be installed in hazardous locations since they pose no short–circuit risk. They can also be installed in open areas since fiber optic cables and connections are impervious to electro–magnetic interference/electro–magnetic pulse (EMI/EMP). The Ship Information Book (SIB) further outlines IC box locations on each specific platform.

408–B.3.3.1 Fibers within IC boxes are installed around the inside edges of the box such that they do not block or otherwise obstruct access to any connections in the box. The fiber is protected from sharp edges and care is taken when attaching the fiber to prevent kinking or cutting. The fiber bends inside the IC box shall not violate the minimum static bend radius in the final installed configuration.

408–B.3.4 CABLE ENTRANCE TO EQUIPMENT AND PENETRATION OF SHIP STRUCTURE

408–B.3.4.1 Cable Entrance to Equipment. Fiber optic cable entrance into equipment employs some of the same devices (i.e., stuffing tubes and multiple cable penetrators (MCPs)) used for electrical cable entrance to equipment. When these devices are used, the methods for installation are the same as for electrical cable. However, since optical fiber cable components (OFCC) are not as rigid as copper conductors, they actually compress when a MCP or stuffing tube is tightened. To ensure the watertight seal is achieved and maintained, the cap (stuffing tube) or nut (MCP) is retightened approximately 24 hours after initial compression.

408–B.3.4.1.1 Where connectors are used for cable entrance to equipment, the cables are installed such that connectors may be easily removed. Suitable amounts of slack cable must also be allowed inside the equipment to allow a minimum of two repair reconnections.

408–B.3.4.2 Cable Penetration of Ship Structure. Fiber optic cable penetrations of ship structures are made by metal stuffing tubes, MCPs and chafing collars or nipples in a manner similar to that of electrical cables. Stuffing tube, MCP block insert, swage tube, and kickpipe sizes to be used for each cable type are identified in the following Table 408–B–2 through Table 408–B–10. Where neither submarines nor surface ships are specified, the parts in the tables are applicable to both.

Table 408–B–2. STEEL STUFFING TUBES SIZES FOR FIBER OPTIC CABLES (SUBMARINES)

Cable Type	Cable O.D. mm (inches) (nominal)	Tube Size	Packing Assembly	
			Part No. M24235/2	Symbol No.
4–Fiber	8.1 (0.32)	1	–*002	2405.2
8–Fiber	11.1 (0.44)	1	–*003	2405.3
36–fiber	20.8 (0.82)	3	–*013	2407.1

NOTE: The asterisk “*” represents item material. The material shall be Neoprene (N) or Silicone (S).

Table 408–B–3. STEEL STUFFING TUBE DATA

Grade Steel		HY–80		HT	
		Tube Size 1	Tube Size 3	Tube Size 1	Tube Size 3
Stuffing tube assembly	Part number M24235/1	–001	–003	–101	–103
Part numbers of components	Tube body (1 required) M24235/1	–010	–012	–110	–112
	Gland nut (2 required) M24235/1	–019	–021	–019	–021
	Lock washer (2 required) M24235/1	–028	–030	–028	–030
Symbol number		2405 HY–80	2407 HY–80	2405–HT	2407–HT

Table 408–B–4. ALUMINUM AND STEEL STUFFING TUBE SIZES FOR FIBER OPTIC CABLE (SURFACE SHIPS)

Cable Type	Cable O.D. mm (inches) (nominal)	Tube Size MIL–S–24235/9 and /10	Packing Assembly MIL–P–16685
4–Fiber	8.1 (0.32)	A	Class 1 and 2
8–Fiber	11.1 (0.44)	B	Class 1 and 2
36–Fiber	20.8 (0.82)	F	Class 1 and 2

Table 408–B–5. STEEL STUFFING TUBE DATA FOR DECKS AND BULKHEADS WITH AND WITHOUT PIPE PROTECTION

Tube Type		Without Pipe Protection			With Pipe Protection		
Tube Size		A	B	F	A	B	F
Stuffing tube assembly	Part number M24235/	10–01	10–02	10–06	09–121	09–122	09–126
Part numbers of components	Tube body (1 required) M24235/	10–31	10–32	10–36	09–151	09–152	09–156
	Gland nut (1 required) M24235/	09–061	09–062	09–066	09–061	09–062	09–066
	Gland ring (1 required) M24235/	09–181	09–182	09–186	09–181	09–182	09–186
Symbol number		1600	1601	1605	1570	1571	1575

Table 408–B–6. SWAGE TYPE ALUMINUM STUFFING TUBE DATA FOR DECKS AND BULKHEADS

Tube Type		Bulkheads			Decks		
Tube Size		A	B	F	A	B	F
Stuffing tube assembly	Part number M24235/17	–031	–032	–036	–091	–092	–096
Part numbers of components	Tube body (1 required) M24235/17	–151	–152	–156	–211	–212	–216
	Gland nut (1 required) M24235/17	–241	–242	–246	–241	–242	–246
	Gland ring (1 required) M24235/17	–271	–272	–276	–271	–272	–276
Symbol number		1731	1732	1736	1791	1792	1796

Table 408–B–7. SWAGE TYPE STEEL STUFFING TUBE DATA FOR DECKS AND BULKHEADS

Tube Type		Bulkheads			Decks		
Tube Size		A	B	F	A	B	F
Stuffing tube assembly	Part number M24235/17	–001	–002	–006	–061	–062	–066
Part numbers of components	Tube body (1 required) M24235/17	–121	–122	–126	–181	–182	–186
	Gland nut (1 required) M24235/09	–061	–062	–066	–061	–062	–066
	Gland ring (1 required) M24235/09	–181	–182	–186	–181	–182	–186
Symbol number		1701	1702	1706	1761	1762	1766

Table 408–B–8. REDUCED DIAMETER SWAGE TYPE ALUMINUM STUFFING TUBE DATA FOR DECKS AND BULKHEADS

Tube Type		Bulkheads			Decks		
Tube Size		A	B	F	A	B	F
Stuffing tube assembly	Part number M24235/18	–031	–032	–036	–091	–092	–096
Part numbers of components	Tube body (1 required) M24235/18	–151	–152	–156	–211	–212	216
	Gland nut (1 required) M24235/17	–241	–242	–246	–241	–242	–246
	Gland ring (1 required) M24235/17	–271	–272	–276	–271	–272	–276
Symbol number		1871	1872	1876	1941	1942	1946

Table 408–B–9. REDUCED DIAMETER SWAGE TYPE STEEL STUFFING TUBE DATA FOR DECKS AND BULKHEADS

Tube Type		Bulkheads			Decks		
Tube Size		A	B	F	A	B	F
Stuffing tube assembly	Part number M24235/18	–001	–002	–006	–061	–062	–066
Part numbers of components	Tube body (1 required) M24235/18	–121	–122	–126	–181	–182	–186
	Gland nut (1 required) M24235/09	–061	–062	–066	–061	–062	–066
	Gland ring (1 required) M24235/09	–181	–182	–186	–181	–182	–186
Symbol number		1821	1822	1826	1911	1912	1916

Table 408–B–10. MCP DATA AND INSERT BLOCK SIZES FOR FIBER OPTIC CABLE

Cable Type	4–Fiber	8–Fiber	36–Fiber
Cable O.D. mm (inches) nominal	8.1 (0.32)	11.1 (0.44)	20.8 (0.82)
Primary insert block part number M24705/1–BN	1508	2011	3021
Alternate insert block part number M24705/1–BN	2008	N/A	N/A
Blanking insert block part number M24705/1–BN	15	20	30
Alternate blanking insert block part number M24705/1–BN	20	N/A	N/A

408–B.4 CABLEWAYS AND CABLE ROUTING

408–B.4.1 GENERAL. The cableways and cable retention devices used by fiber optic cables are the same as those designated for and used by electrical cables. Most fiber optic cable runs share the same cableways with electrical signal and power cables. By using these cableways, the fiber optic cables will have the same protection from battle and mechanical damage as their electrical counterparts. These same cableways also allow maximum athwartship and vertical separation of fiber optic cables for systems requiring alternate signal paths for reliability and survivability.

408–B.5 CONNECTORS AND CONNECTIONS

408–B.5.1 GENERAL. For termination of fibers, two types of connectors and a mechanical splice have been approved. MIL–C–28876 multiple terminus connectors are used to connect the end user equipment to the fiber optic cable plant. These connectors are ruggedized and sealed against the environment and can be used in unprotected areas.

408–B.5.2 The MIL–C–83522/16 single terminus connectors are used to connect individual OFCCs. They are used in fiber links that are subject to periodic disconnections and reconnection, and are found in most other links because they are easier to reconfigure than splices. Single terminus connectors are not sealed, so they should always be located inside an equipment or on a patch panel in an IC box.

408–B.5.3 The DOD–S–24623/4 mechanical splice functions the same as the single terminus connector except that it experiences lower optical loss. The splice is generally only used in multi–mode fiber links when optical loss must be minimized. The splice also is used for connections in single mode fiber links. The splice must be installed in an equipment, or in an IC box for protection.

408–B.6 INSPECTION AND TESTING REQUIREMENTS

NOTE

Inspection procedures for equipment on arrival are included herein for information purposes only. The procedures are normally for shipyard use. However, all other procedures for inspection and testing are requirements for the ships force. For detailed methods of the testing procedures, refer to the paragraphs on Test equipment in this document.

408–B.6.1 INSPECTION PROCEDURES FOR EQUIPMENT ON ARRIVAL. All fiber optic cable and associated fiber optic components undergo visual inspection upon receipt. This inspection verifies the cable and components are the correct MIL–Spec approved items and do not appear to be damaged. The cables, while still on the shipping reels, undergo additional testing to ensure they are mechanically and optically sound. A cable attenuation test is performed on cables which have no connectors or splices installed or cables that have connectors/splices only on one end. A cable assembly link loss test is performed on cables that have connectors or splices installed on both ends.

408–B.6.2 INSPECTION PROCEDURES TO CHECK INSTALLATION. Tests performed to verify proper installation of a fiber optic cable topology are as follows:

a. Pre–installation Test.

b. Installation Test.

c. Post–installation Test.

408–B.6.2.1 Pre–Installation Test. The pre–installation test includes a visual inspection of the cable and associated components, and a cable continuity test. The cable continuity test is performed to verify there is no major damage or breakage. These tests are performed just prior to installation in the cableways.

408−B.6.2.2 Installation Test. The installation test for fiber optic cable is a two–phase step performed just after the cable is installed in the cableways.

Phase 1. The visual inspection and cable continuity test portions of the pre–installation test are repeated. These tests verify that the fibers were not damaged or broken when the cable was pulled through the cableway.

Phase 2. After installation of connectors or splices on the cable ends, such that the cable is terminated on both ends, the cable link loss test is performed. This test ensures that optical losses induced by associated components are within acceptable limits and that continuity of each fiber between interconnection devices has been maintained.

408−B.6.2.3 Post–Installation Test. The post–installation test is performed after all fiber optic topology links have been installed. A fiber optic cable topology end–to–end attenuation test is performed to ensure attenuation over a series of optical links is within specified system acceptable limits for optic power transmission.

APPENDIX C

FIBER OPTIC REPAIR INFORMATION TABLES FROM MIL–STD–2042(SH)

408–C.1. INTRODUCTION

This appendix lists equipment and materials for fiber optic repair. These lists shall be utilized to maximize the effectiveness of repairs to the fiber optic cable topology.

408–C.2. CABLE JACKET REPAIR

These items are for repairing the damaged outer jacket of a cable with kevlar strength members intact Table 408–C–1 includes safety and repair equipment and materials for repair using a wrap–around sleeve with rail closure.

Table 408–C–1. WRAP–AROUND SLEEVE WITH RAIL CLOSURE

Description	Quantity
Safety glasses	1
Ruler	1
Electricians knife	1
Emery cloth (or fine file)	As required
Adhesive and sealant tape (Raychem Thermofit S1030 or equal)	As required
Repair sleeve	1
Heat gun (Raychem 500B or equal)	1
Alcohol bottle with alcohol/2–propanol	1
Wipes	As required
Canned air (or compressed air)	As required

NOTE

The cable jacket repair sleeve material shall meet the requirements of MIL–I–23053/15. The material shall be coated with a heat–activated adhesive and fabricated into a wrap around sleeve with a rail closure system.

408–C.3. REPAIR SLEEVE DIMENSIONS (WRAP–AROUND)

Table 408–C–2 identifies wrap–around repair sleeve dimensions and contains repair sleeve cross–referencing information to aid in selecting the correct repair sleeve.

408–C.4. MATERIALS FOR TUBE SLEEVE REPAIR

Materials used in accomplishing repairs by the tube sleeve method are the same as for the wrap–around sleeve with rail closure. Refer Table 408–C–1 for identification of materials and equipment required when performing a repair by the tube sleeve repair method.

408–C.5. TUBE SLEEVE REPAIR DIMENSIONS

Table 408–C–3 identifies repair dimensions for tube sleeve repairs and references information to aid in selecting the correct repair sleeve tube.

Table 408–C–2. REPAIR SLEEVE DIMENSIONS (WRAP–AROUND)

Cable Type	Cable O.D. nominal mm (inches)	B dimension mm (inches)	Repair Sleeve Dimensions mm (inches)			
			Length (minimum)	Rail to Rail		Wall Thickness after Shrinking (±10%)
				Expanded (minimum)	Recovered (maximum)	
4–fiber	8.1 (.32)	76 (3.0)	A + 2B	45.7 (1.8)	23.9 (.94)	2.0 (0.08)
8–fiber	11.1 (.44)	76 (3.0)	A + 2B	45.7 (1.8)	23.9 (.94)	2.0 (0.08)
36–fiber	20.8 (.82)	76 (3.0)	A + 2B	79.8 (3.14)	48.5 (1.91)	2.0 (0.08)

Table 408–C–3. REPAIR SLEEVE DIMENSIONS

Cable Type	Cable O.D. nominal mm (inches)	B Dimension mm (inches)	Repair Sleeve Dimensions mm (inches)			
			Length (mini-mum)	Rail to Rail		Wall Thickness After Shrinking (±10%)
				Expanded (minimum)	Recovered (maximum)	
4–Fiber	8.1 (.32)	201 (4.0)	A + 2B	19.1 (0.75)	5.6 (0.22)	3.0 (0.11)
8–Fiber	11.1 (.44)	101 (4.0)	A + 2B	19.1 (0.75)	5.6 (0.22)	3.0 (0.11)
36–Fiber	20.8 (.82)	101 (4.0)	A + 2B	28.0 (1.10)	9.6 (0.38)	3.0 (.12)

408–C.6. MATERIALS FOR RUBBER TAPE REPAIR METHOD

Table 408–C–4 identifies equipment and materials to be used when performing a repair using the rubber tape repair method.

Table 408–C–4. MATERIALS FOR RUBBER TAPE REPAIR METHOD

Description	Quantity
Safety glasses	1
Ruler	1
Electricians knife	1
Emery cloth (or fine file)	As required
Adhesive and sealant tape (Raychem Thermofit S1030 or equal)	As required
Heat gun (Raychem 500B or equal)	1
Fiberglass tape (1 in.)	As required
Electrical coating (3M Scotch Kote or equal)	As required
Alcohol bottle with alcohol/2–propanol	1
Wipes	As required
Canned air (or compressed air)	As required

408–C.7. MATERIALS FOR WRAPAROUND SLEEVE WITH ADHESIVE CLOSURE

Materials used in accomplishing repairs by the wraparound sleeve with adhesive closure method are the same as for the wrap–around sleeve with rail closure. Refer Table 408–C–1 for identification of materials and equipment required when performing a repair by the wraparound sleeve with adhesive closure method.

408–C.8. WRAPAROUND SLEEVE WITH ADHESIVE CLOSURE REPAIR DIMENSIONS

Table 408–C–5 identifies repair dimensions for wraparound sleeve with adhesive closure repairs and references information to aid in selecting the correct repair sleeve. Wraparound sleeves with adhesive closures are only available for the 36–fiber cable.

408–C.9. ROTARY SPLICE FERRULE INSTALLATION

Table 408–C–6 identifies the equipment and materials for installing MIL–S–24623/4 rotary mechanical splices onto fiber optic cable.

408–C.10. ROTARY SPLICE ALIGNMENT AND MATING

Table 408–C–7 identifies equipment and materials for aligning and mating the MIL–S–24623/4 rotary mechanical splice.

Table 408–C–5. WRAPAROUND SLEEVE WITH ADHESIVE CLOSURE REPAIR DIMENSIONS

Cable Type	Cable O.D. nominal mm (inches)	B Dimension mm (inches)	Repair Sleeve Dimensions mm (inches)			
			Length (minimum)	Rail to Rail		Wall Thickness After Shrinking (±10%)
				Expanded (minimum)	Recovered (maximum)	
36–Fiber	20.8 (.82)	76 (3.0)	A + 2B	31.8 (1.25)	12.7 (.50)	2.0 (0.08)

408–C.11. SINGLE TERMINUS CONNECTOR INSTALLATION

Table 408–C–8 identifies equipment and materials for installing the MIL–C–83522/16 single terminus connector onto fiber optic cable.

408–C.12. MULTIPLE TERMINUS CONNECTORS WITH REMOVABLE BACKSHELLS

Table 408–C–9 identifies equipment and materials necessary to install MIL–C–28876 multiple terminus connectors with removable backshells on fiber optic cables.

NOTE

Refer Table 408–C–11 for connectors with non–removable backshells.

408–C.13. CABLE STRIPPING

Table 408–C–10 provides information to determine cable stripping dimensions for installation of multiple terminus connectors with removable backshells.

408–C.14. MULTIPLE TERMINUS CONNECTORS WITH NON–REMOVABLE BACKSHELLS

Table 408–C–11 identifies equipment and materials necessary to install MIL–C–28876 multiple terminus connectors with non–removable backshells on fiber optic cables.

NOTE

Table 408–C–11 is not applicable for connector backshells with part numbers M28876/27, M28876/28, and M28876/29. Refer Table 408–C–9 for connectors with removable backshells.

408–C.15. CABLE STRIPPING

Table 408–C–12 provides information to determine cable stripping dimensions for installation of multiple terminus connectors with non–removable backshells.

Table 408–C–6. MATERIALS FOR ROTARY MECHANICAL SPLICE INSTALLATION

Description	Quantity
Wipes (NAVSEA DWG 6872812–18 or equal)	As required
Alcohol bottle with alcohol/2–propanol	1
Canned air or compressed air	As required
OFCC strip tool (NAVSEA DWG 6872812–10 or equal)	1
Kevlar shears (NAVSEA DWG 6872812–16 or equal)	1
UV absorbing safety glasses	1
Buffer strip tool (NAVSEA DWG 6872812–9 or equal)	1
UV cure adhesive (MIL–A–24793)	As required
Dispensing needles (NAVSEA DWG 6872812–22 or equal)	As required
UV blocking shield	As required
UV curing lamp and base (NAVSEA DWG 6872812–13 or equal)	1
Cleaver (NAVSEA DWG 6872812–7 or equal)	1
Utility knife	1
Glass polishing plate (NAVSEA DWG 6872812–3 or equal)	1
Polishing paper, 8 mm, aluminum oxide, paper backed (NAVSEA DWG 6872812–19 or equal)	As required
Polishing paper, 0.3 mm, aluminum oxide, paper backed (NAVSEA DWG 6872812–20 or equal)	As required
Polishing tool (NAVSEA DWG 6872812–4 or equal)	1
Water bottle (sealable type)	1
7x eye loupe	1
Protective caps (plastic)	As required

Table 408–C–7. MATERIALS FOR THE ALIGNING AND MATING OF A ROTARY MECHANICAL SPLICE BOX

Description	Quantity
Safety glasses	1
Index matching gel (MIL–M–24794)	As required
Alignment clip tool (NAVSEA DWG 6872812–01 or equal)	1
Splice alignment tool (NAVSEA DWG 6872812–05 or equal)	1
Test jumpers (in accordance with table 6C1–III in Part 6 of this standard)	As required
Optical loss test set (NSN 7Z 6625 01 304 1739) or equal	1
Alcohol bottle with alcohol/2–propanol	1
Wipes (NAVSEA DWG 6872812–18 or equal)	As required

Table 408–C–8. MATERIALS FOR SINGLE TERMINUS CONNECTOR INSTALLATION

Description	Quantity
Wipes (NAVSEA DWG 6872811–18)	As required
Alcohol bottle with alcohol/2–propanol or equal	1
Canned air or compressed air	As required
OFCC strip tool (NAVSEA DWG 6872811–10 or equal)	1
Kevlar shears (NAVSEA DWG 6872811–16)	1
Safety glasses	1
Ruler	1
Buffer strip tool (NAVSEA DWG 6872811–9 or equal)	1
Cleaning wire (NAVSEA DWG 6872811–24 or equal)	As required
Epoxy (MIL–A–24792)	As required
Syringe with dispensing needles (NAVSEA DWG 6872811–22 or equal)	As required
Cure adapters (NAVSEA DWG 6872811–27 or equal)	As required
Crimp tool (NAVSEA DWG 6872811–1 or equal)	1
Die for crimp tool (NAVSEA DWG 6872811–2 or equal)	1
Heat gun (Raychem 500B or equal)	1
Curing oven (NAVSEA DWG 6872811–13 or equal)	1
Holder block	As required
Cleaver (NAVSEA DWG 6872811–7 or equal)	1
Glass polishing plate (NAVSEA DWG 6872811–3 or equal)	1
Polishing paper (5 mm aluminum oxide, foam backed) (NAVSEA DWG 6872811–20 or equal)	As required
Polishing tool (NAVSEA DWG 6872811–4 or equal)	1
Polishing paper (1 mm aluminum oxide, mylar backed) (NAVSEA DWG 6872811–19 or equal)	As required
Water bottle (sealable type)	1
Optical microscope 400X (NAVSEA DWG 6872811–25 or equal)	1
Protective caps (plastic)	As required

Table 408–C–9. MULTIPLE TERMINUS CONNECTOR WITH REMOVABLE BACKSHELL INSTALLATION EQUIPMENT AND MATERIALS

Description	Quantity
Wipes (NAVSEA DWG 6872813–22 or equal)	As required
Ruler	1
Alcohol bottle with alcohol/2–propanol or equal (sealable type)	1
Canned air or compressed air	As required
Cable jacket stripping tool (NAVSEA DWG 6872813–8 or equal)	1
Masking tape	As required

Table 408–C–9. MULTIPLE TERMINUS CONNECTOR WITH REMOVABLE BACKSHELL INSTALLATION EQUIPMENT AND MATERIALS (Cont)

Description	Quantity
Kevlar shears (NAVSEA DWG 6872813–16 or equal)	1
OFCC strip tool (NAVSEA DWG 6872813–10 or equal)	1
Safety glasses	1
Buffer strip tool (NAVSEA DWG 6872813–9 or equal)	1
Cleaning wire (NAVSEA DWG 6872813–32 or equal)	As required
Epoxy (MIL–A–24792)	As required
Syringe with dispensing needles (NAVSEA DWG 6872813–27 or equal)	As required
Crimp tool (NAVSEA DWG 6872813–17 or equal)	1
Razor blade	1
Cure adapters (NAVSEA DWG 6872813–19 or equal)	As required
Curing oven (NAVSEA DWG 6872813–19 or equal)	1
Cable stand (NAVSEA DWG 6872813–19 or equal)	1
Cable stand ring (NAVSEA DWG 6872813–19 or equal)	1
Cable clip (NAVSEA DWG 6872813–19 or equal)	1
Cleaver (NAVSEA DWG 6872813–7 or equal)	1
Polishing paper (5 mm aluminum oxide, foam backed) (NAVSEA DWG 6872813–24 or equal)	As required
Polishing tool ceramic termini (NAVSEA DWG 6872813–18 or equal)	1
Terminus insertion tool (NAVSEA DWG 6872813–2 or equal)	1
Terminus insertion tool 90° (NAVSEA DWG 6872813–15 or equal)	1
Glass polishing plate (NAVSEA DWG 6872813–3 or equal)	1
7X eye loupe	1
Polishing paper (1 mm aluminum oxide, mylar backed) (NAVSEA DWG 6872813–23 or equal)	As required
Water bottle (sealable type)	1
Terminus removal tool (NAVSEA DWG 6872813–6 or equal)	1
Optical microscope 400X (NAVSEA DWG 6872813–28 or equal)	1
Alignment sleeve insertion and removal tool (ceramic termini)(NAVSEA DWG 6872813–4 or equal)	1
Loctite or equal	As required
“O”–ring lubricant (Bray Cote 609 or equal)	As required
Adjustable wrench	1
Backshell grip	1
Protective caps (plastic)	As required

Table 408–C–10. MULTIPLE TERMINUS CONNECTOR WITH REMOVABLE BACK-SHELL CABLE STRIPPING DIMENSIONS

Connector Shell Size	Backshell Configuration	Dimensions mm (in)					
		Long Backshell			Short Backshell		
		A	B	C	A	B	C
13 (Four fiber)	Straight	135 (5.3)	30 (1.2)	19 (0.75)	117 (4.6)	30 (1.2)	19 (0.75)
	45°	150 (5.9)	30 (1.2)	19 (0.75)	130 (5.1)	30 (1.2)	19 (0.75)
	90°	150 (5.9)	30 (1.2)	19 (0.75)	130 (5.1)	30 (1.2)	19 (0.75)
15 (Eight fiber)	Straight	161 (6.3)	30 (1.2)	19 (0.75)	135 (5.3)	30 (1.2)	19 (0.75)
	45°	155 (6.1)	30 (1.2)	19 (0.75)	130 (5.1)	30 (1.2)	19 (0.75)
	90°	155 (6.1)	30 (1.2)	19 (0.75)	130 (5.1)	30 (1.2)	19 (0.75)

Table 408–C–11. MULTIPLE TERMINUS CONNECTOR WITH NON–REMOVABLE BACKSHELL INSTALLATION EQUIPMENT AND MATERIALS

Description	Quantity
Ruler	1
Wipes (NAVSEA DWG 6872813–22 or equal)	As required
Alcohol bottle with alcohol/2–propanol or equal (sealable type)	1
Canned air or compressed air	As required
Cable jacket stripping tool (NAVSEA DWG 6872813–8 or equal)	1
Masking tape	As required
“O”–ring lubricant (Bray Cote 609 or equal)	As required
O–ring tools (NAVSEA DWG 6872813–5 or equal)	As required
Spanner wrench (NAVSEA DWG 6872813–5 or equal)	1
Torque wrench adapters (NAVSEA DWG 6872813–5 or equal)	As required
Hex adapter (NAVSEA DWG 6872813–29)	1
Torque wrench (NAVSEA DWG 6872813–1 or equal)	1
Heat gun	1
Kevlar shears (NAVSEA DWG 6872813–16 or equal)	1
OFCC strip tool (NAVSEA DWG 6872813–10 or equal)	1
Safety glasses	1
Buffer strip tool (NAVSEA DWG 6872813–9 or equal)	1
Cleaning wire (NAVSEA DWG 6872813–32 or equal)	As required
Epoxy (MIL–A–24792)	As required
Syringe with dispensing needles (NAVSEA DWG 6872813–27 or equal)	As required
Crimp tool (NAVSEA DWG 6872813–17 or equal)	1
Razor blade	1

Table 408–C–11. MULTIPLE TERMINUS CONNECTOR WITH NON–REMOVABLE BACKSHELL INSTALLATION EQUIPMENT AND MATERIALS (Cont)

Cure adapters (NAVSEA DWG 6872813–19 or equal)	As required
Curing oven (NAVSEA DWG 6872813–19 or equal)	1
Cable stand (NAVSEA DWG 6872813–19 or equal)	1
Cable stand ring (NAVSEA DWG 6872813–19 or equal)	1
Cable clip (NAVSEA DWG 6872813–19 or equal)	1
Cleaver (NAVSEA DWG 6872813–7 or equal)	1
Polishing paper (5 mm aluminum oxide, foam backed) (NAVSEA DWG 6872813–24 or equal)	As required
Polishing tool ceramic termini (NAVSEA DWG 6872813–18 or equal)	1
Terminus insertion tool (NAVSEA DWG 6872813–2 or equal)	1
Terminus insertion tool 90° (NAVSEA DWG 6872813–15 or equal)	1
Glass polishing plate (NAVSEA DWG 6872813–3 or equal)	1
7X eye loupe	1
Polishing paper (1 mm aluminum oxide, mylar backed) (NAVSEA DWG 6872813–23 or equal)	As required
Water bottle (sealable type)	1
Terminus removal tool (NAVSEA DWG 6872813–6 or equal)	1
Optical microscope 400X (NAVSEA DWG 6872813–28 or equal)	1
Alignment sleeve insertion and removal tool (ceramic termini)(NAVSEA DWG 6872813–4 or equal)	1
Backshell grip	1
Adjustable wrench	1
Protective caps (plastic)	As required

408–C.16. MULTIPLE TERMINUS CONNECTORS WITH INSERT RETENTION NUTS

The materials necessary to install MIL–C–28876 multiple terminus connectors with insert retention nuts are the same as for the MIL–C–28876 multiple terminus connector with non–removable backshells. Refer Table 408–C–11 for identification of materials and equipment required when installing MIL–C–28876 multiple terminus connectors with insert retention nuts.

408–C.17. CABLE ENTRANCE TO EQUIPMENT VIA NYLON STUFFING TUBE.

Table 408–C–13 identifies equipment and materials for installing cables into equipment via nylon stuffing tubes.

408–C.18. NYLON STUFFING TUBE SIZES

Table 408–C–14 and Table 408–C–15 below, identify specific cable sizes, applicable packing assemblies, and part numbers for fiber optic cable entry to equipment via nylon stuffing tubes.

408–C.19. CABLE FORMING AND SHAPING

Table 408–C–17 identifies equipment and materials for cable forming and shaping.

408–C.20. CABLE ENTRANCE TO EQUIPMENT VIA MULTIPLE CABLE PENETRATOR

Table 408–C–16 identifies equipment and materials for installing cables into equipment via multiple cable pentrator.

Table 408–C–12. MULTIPLE TERMINUS CONNECTOR WITH NON–REMOVABLE BACKSHELL CABLE STRIPPING DIMENSIONS

Connector Shell Size	Backshell Configuration	Dimensions mm (in)		
		A	B	C
13 (Four fiber)	Straight	110 (4.3)	30 (1.2)	19 (0.7)
	45°	110 (4.3)	30 (1.2)	19 (0.75)
	90°	110 (4.3)	30 (1.2)	19 (0.75)
15 (Eight fiber)	Straight	110 (4.3)	30 (1.2)	19 (0.75)
	45°	120 (4.7)	30 (1.2)	19 (0.75)
	90°	120 (4.7)	30 (1.2)	19 (0.75)

Table 408–C–13. NYLON STUFFING TUBE INSTALLATION MATERIALS AND EQUIPMENT

Description	Quantity
Safety glasses	1
Ruler	1
Deburring tool (or equivalent)	1
Paint scraper	1
Emery cloth	As required
Cable jacket stripping tool (NAVSEA DWG 6872812–08 or equal)	1
Kevlar shears (NAVSEA DWG 6872812–16 or equal)	1
Open end wrench (sized to fit locknut)	1
Spanner wrench (sized to fit cap)	1
RTV silicone rubber (Silastic 731731 or equal)	As required
Primer (type to suit metal)	As required
Talc (soap stone)	As required
Alcohol bottle with alcohol/2–propanol	1
Wipes	As required
Canned air (or compressed air)	As required

Table 408–C–14. NYLON STUFFING TUBE SIZES FOR FIBER OPTIC CABLE

Cable Type	Cable O.D. mm (inches) Nominal	Tube Size	Packing Assembly Part No. M19622/	Packing Assembly Opening Mm (inches)
4–Fiber	8.1 (0.32)	2	17–0001	8.26 (0.325)
8–Fiber	11.1 (0.44)	3	18–0018	12.0 (0.472)
36–Fiber	20.8 (0.82)	5	20–0003	21.7 (0.853)

Table 408–C–15. NYLON STUFFING TUBE DATA

Stuffing Tube Sizes		Tube Size 2	Tube Size 3	Tube Size 5
Straight tube	Tube part number M19622/	1–002	1–003	1–0006
	"O"–ring part number MS28775–	214	216	226
Angle tube	Tube part number M19622/	2–002	2–003	2–006
	"O"–ring part number MS28775–	212	216	226
NPT Tube	Tube part number M19622/	3–002	3–003	3–005
	NPT Tap mm (inches)	19 (0.75)	25 (1.0)	38 (1.5)
"Y" Tube	Tube part number M19622/	4–02	4–03	N/A
	"O"–ring part number MS28775–	214	216	N/A

Table 408–C–16. MULTIPLE CABLE PENETRATOR INSTALLATION MATERIALS AND EQUIPMENT

Description	Quantity
Safety glasses	1
Ruler	1
Tallow (Hevi–Duty/Nelson AA0099 or equal)	As required
Open end wrench (sized to fit wedgepack nut)	1
Cable jacket stripping tool (NAVSEA DWG 6872812–08 or equal)	1
Kevlar shears (NAVSEA DWG 6872812–16 or equal)	1

Table 408–C–17. CABLE FORMING AND SHAPING MATERIALS AND EQUIPMENT

Description	Quantity
Safety glasses	1
Ruler	1
Self–clinching straps (MIL–S–23190 or commercial)	As required
Lacing (Nylon or equal)	As required
Synthetic tubing	As required
Heat shrink tubing (MIL–T–23053/5)	As required
Heat gun (Raychem 500B or equal)	1
Open end wrench	1
Alcohol bottle with alcohol/2–propanol	1
Wipes (NAVSEA DWG 6872812–18 or equal)	As required
Canned air (NAVSEA DWG 6872812–17 or equal)	As required

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